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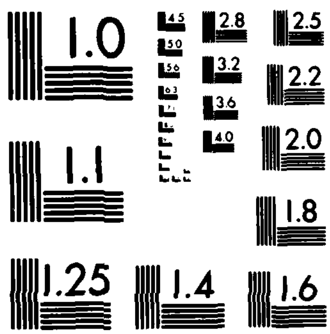


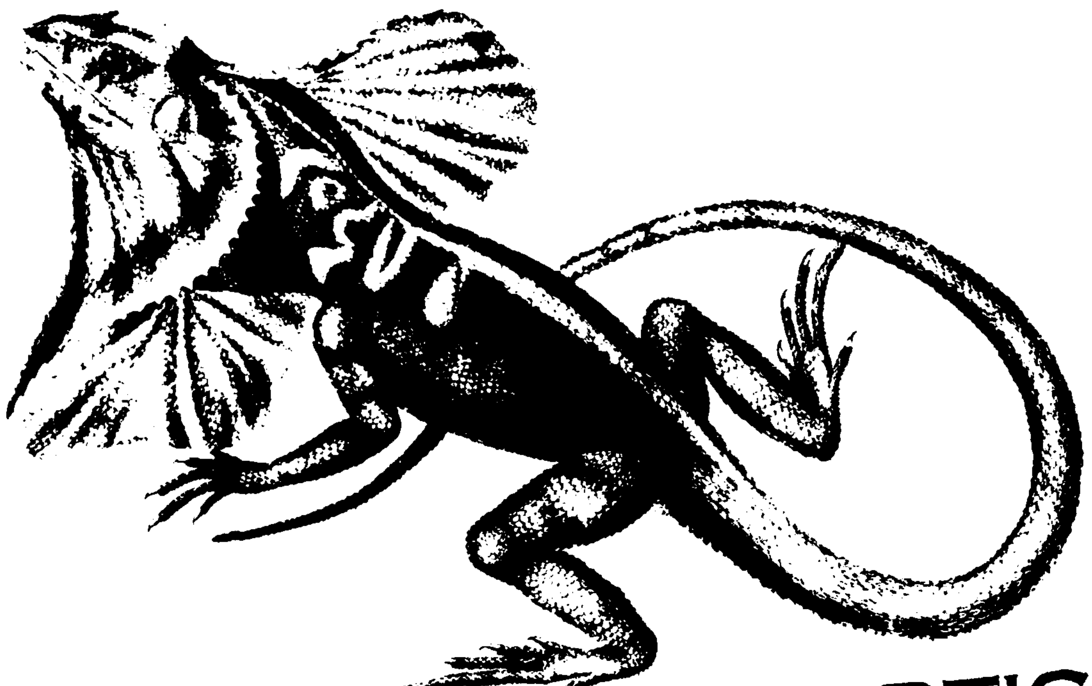
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

OCTOBER TO DECEMBER 1984 VOL. 9, NO. 4

12

SCIENTIFIC BULLETIN

DEPARTMENT OF THE NAVY OFFICE OF NAVAL RESEARCH FAR EAST
DEPARTMENT OF THE AIR FORCE OFFICE OF SCIENTIFIC RESEARCH FAR EAST



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This ~~is a~~ quarterly publication present~~ing~~ articles covering recent developments in Far Eastern (particularly Japanese) scientific research. It is hoped that these reports (which do not constitute part of the scientific literature) will prove to be of value to scientists by providing items of interest well in advance of the usual scientific publications. The articles are written primarily by members of the staff of ONR Far East and the Air Force Office of Scientific Research with certain reports also being contributed by visiting state-side scientists. Occasionally, a regional scientist will be invited to submit an article covering his own work, considered to be of special interest.

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18. Subject Terms (Key Words) continued

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Research programs
Science and technology
Semiconductor research
III-V compound materials
Characterization
Japan
Universities
Solid state devices
Material technologies
Silicon
Photomolecular layer epitaxy
Lasers
High strength steels
Marine structures
Welding technology
Japanese shipyards
Offshore structures
Electrochemistry
Australia
Aluminum technology
Electrodes
Industrial technology
Fifth Generation Computer Sytem Project
ICOT
Japan
Personal Sequential Inference (PSI) Machine
Software development
Photoelectrochemistry
Solar energy conversion
Materials
Japan
Storage
Ocean surface
Wave dynamics
Radio probing
Turbulence
World climate

CONTRIBUTORS

Nicholas A. Bond, Jr., currently the Director of ONR Far East, is an engineering psychologist on leave from California State University at Sacramento. Dr. Bonds's main interests are in man-machine interface, decision aiding, and the maintenance of complex systems by humans. Dr. Bond recently completed an assignment at ONR London. He is a fellow of the American Psychological Association.

Wayne V. Burt received his Ph.D. in physical oceanography from the University of California, Los Angeles, in 1952. Dr. Burt is currently a professor at Oregon State University, Corvallis, Oregon. He served as a liaison scientist of oceanography and meteorology for the Office of Naval Research, London, from 1979 to 1980. Dr. Burt's current interests are in sea-air interaction and endeavoring to obtain historical weather data for the north Pacific from old Spanish ship's logs.

Thomas W. Eagar, a liaison scientist with ONRFE, is on leave from his position as associate professor of materials engineering at the Massachusetts Institute of Technology. Dr. Eagar's professional interests are broadly in manufacturing processes for metals and ceramics with more specific interest in welding and joining technology.

P. F. Iampietro, a physiologist, is on the scientific staff of the Air Force Office of Scientific Research, Far East. Previously he directed the Air Force basic research program in the life sciences. His scientific interests include environmental physiology and a more recent interest in membrane phenomena. Dr. Iampietro is a member of the American Physiological Society.

Michael J. Koczak is professor of materials engineering at Drexel University, Philadelphia, Pennsylvania. Dr. Koczak was a liaison scientist on the staff of ONR Far East from July 1982 until September 1983. Dr. Koczak's specialities include physical and powder metallurgy, composite materials, and ceramics.

Gleb Mamantov is a professor of chemistry at the University of Tennessee where, since 1979, he has also been the head of the Department of Chemistry. Dr. Mamantov received his Ph.D. from Louisiana State University in 1957. Dr. Mamantov's professional interests include spectroscopy in molten salts, chemistry, electrochemistry, high temperature batteries, and matrix isolation spectroscopy. Professor Mamantov is a fellow of the American Institute of Chemists and a member of the American Chemical Society.

Harry I. McHenry has recently completed an assignment as a liaison scientist with ONRFE; Dr. McHenry is a supervisory metallurgist with the National Bureau of Standards in Boulder, Colorado. He received his Ph.D. from Lehigh University in 1970. Dr. McHenry's principal duties are to conduct fracture mechanics research relating to the structural safety of ships, pipelines, offshore structures, and cryogenic systems. Prior to going to NBS in 1974, Dr. McHenry served as a project structures engineer for General Dynamics Corporation (1963-1974), where he applied fracture mechanics to the design and evaluation of aircraft structures.

Raul Mendez is an assistant professor at the U. S. Naval Postgraduate School and is currently a visiting adjunct professor from the Courant Institute of New York University in a collaboration effort with Tokyo University. Dr. Mendez received a Ph.D in applied

mathematics from the University of California at Berkeley in December 1977. Dr. Mendez' main research interests lie in computational fluid dynamics and supercomputers.

Yoon Soo Park is currently a senior scientist with the Air Force Office of Scientific Research, Far East. Prior to his assignment in Japan in September 1983, Dr. Park was a task manager and research physicist at the Avionics Laboratory, Air Force Wright Aeronautical Laboratories. His research interests lie in the areas of solid state physics, electronic materials and devices. Dr. Park is a fellow of the American Physical Society and a senior member of IEEE.

Kenneth M. Sancier received his Ph.D in physical chemistry from the Johns Hopkins University and is a physical chemist at SRI International. Dr. Sancier's research interests are in photochemistry related to solar energy conversion, energy transfer processes in solution and between gases and solids, and biochemical processes. Dr. Sancier is a member of the American Chemical Society.

Seikoh Sakiyama, Science Advisor of ONR Far East, has had considerable industrial experience in laboratory chemistry, electronic instrumentation, and quality control methodology. His interests include computer science, linguistics, and energy technology.

Ming-Yang Su has been an oceanographer at the Naval Ocean Research and Development Activity, NSTL, Mississippi, since 1976. He received his Ph.D in fluid mechanics from the University of Minnesota and worked in the aerospace industry for nine years. His recent interests are nonlinear dynamics of ocean surface waves, wave-current interactions, turbulence and oceanic upper layer mixing. Dr. Su is a member of the American Meteorological Society, American Geophysical Union, and American Physical Society.

CONTENTS

Cover: "Erimaki Tokage," or the Frilled Lizard (*Chlamydosaurus Kingii*), is found in Australia and has become a well-loved creature in Japan. The lizard can adopt a bipede mode of locomotion, trotting on its hind legs, its forepaws hanging down. It "frills" its collar-like ruff to determine enemies; the frill display also functions in courtship. The illustration on the cover first appeared in 1854 in *Erpetologie Générale ou Histoire Naturelle Complete des Reptiles* and was reproduced in the book, *Australia's Animals Discovered,* by Peter Stanbury and Graeme Phipps, publisher Pergamon Press (Australia). They have kindly consented to it being displayed again on the cover of the *Scientific Bulletin.*

JAPANESE PLANS FOR AN OFFSHORE CITY

Due to a severe shortage of land, Japan has made extensive use of artificial offshore islands for expansion. For the past two and one-half years, Dr. Kiyohide Terai and a team of engineers from Nippon Telegraph and Telephone Public Corporation have been working on the design of an offshore "Ocean Communications City." The size of their proposed city is enormous. The city would not be built on refilled ocean bottom as past projects, but would stand 100 km offshore on 10,000 ten-m-diameter steel legs in 80-m-deep ocean. The platform would be 5 km by 5 km with four 20-m-high levels. Estimated residence capacity is one million people. The projected cost is $125.0 billion over 20 years.

One might ask why anyone would want to build such a mammoth structure? One reason is that even at a cost of $125,000 per person, such a city is competitive with the cost of land and buildings in many Japanese cities such as Tokyo. Another reason is that any project that consumes 60 million tons of steel as this one, will provide a great number of jobs for many years. This is confirmed by interest in this project by firms such as Mitsui, Nippon Steel and Komatsu. Yet another reason for this city, should it be built, is a demonstration of Japanese technology. The design calls for development of 120 km per hour hovercraft of 50 ton capacity (increasing in time to 1000 to 2000 ton capacity) to connect the "city" to land; of a totally electric, public passenger car transportation system within the city; of tomato and cucumber vines genetically engineered to produce 10,000 fruit per plant and much, much more.

Whether Dr. Terai and his engineers can convince Japanese industry to invest in such a tremendous project or not is problematical; nevertheless, this development team certainly shows that Japanese planners are looking well beyond conventional ideas and designs.

Thomas W. Eagar
ONRFE/AFOSRFE

GaAs MESFET ON Si SUBSTRATE

The Oki Electric Industry Company, Ltd., has announced the fabrication of MESFET on a Si substrate by means of a Ge interlayer. The structure consists of a 1600 Å Ge layer grown epitaxially on (100) Si by the ionized cluster beam (ICB) technique, a 0.5 μm thick buffer layer of five pairs of GaAs/GaAlAs, a 1.8 μm V-doped, semi-inlating GaAs layer, and a 1 μm undoped GaAs layer. All GaAs layers were grown by MOCVD. The undoped GaAs layer was implanted with 60 keV, $1.5\text{-}2.5 \times 10^{-2}$ cm^{-2} Si for an active layer and with 100 keV, 1.5×10^{13} cm^{-2} Si for an n+ layer. A MESFET was fabricated with a self-aligned W-Al gate having Lg=0.5 μm. Au/Ge-Ni-Au was used for ohmic contacts. Both fabricated E- and D-MESFETs showed transconductances of 85 mS/mm. A 17-stage ring oscillator comprising these E/D MESFETs exhibited a minimum delay time of 66.5 ps/gate at power dissipation of 2.3 mW/gate and a minimum power delay product of 14.2 fj/gate. The work by Oki demonstrates the first GaAs MESFETs fabricated on a Si substrate. Japanese efforts to integrate GaAs on a Si substrate is becoming a reality.

Yoon Soo Park
ONRFE/AFOSRFE

GROWTH OF HIGHLY UNIFORM GaAs LAYERS ON THREE-INCH SUBSTRATES BY LOW PRESSURE MOCVD

The NEC Corporation has recently reported on the growth of highly uniform GaAs layers by low pressure MOCVD. A horizontal-type reaction chamber was employed and a three-inch substrate was placed in parallel with the direction of gas flow. To improve uniformity, the substrate was rotated at 12 rpm. At the substrate temperature of 700°C, the total pressure of 100 Torr, the total flow rate of 5 ℓ/min, undoped and Se-doped layers were grown with the growth rate of 8-9 Å/sec. The thickness and carrier concentration uniformity were found to be less than ±2.6% and ±3.5%, respectively. The work represents a substantial advance in MOCVD production capability.

Yoon Soo Park
ONRFE/AFOSRFE

GROWTH OF FIVE-INCH DIAMETER GaAs

The Sumitomo Electric Industries has announced the growth of five-inch diameter, undoped semi-insulating crystals by the LEC method. A five-inch diameter crystal was pulled using the six-inch PB-V crucible in the puller used for the three-inch diameter crystal growth (direct synthesis, upper axis rotation: 5 rpm; bottom axis rotation: 20 rpm; pulling rate: 5-6 mm/h, pressure: 8 atm). Computer-controlled automatic diameter control was employed for growth. By varying control parameters, the diameter of the crystal was controlled within an accuracy of ±1.5 - ±2.5 mm. EPD distributions in the wafers from the seed end of the five-inch crystals showed the U-shape instead of the W-shape. The EPD of the five-inch crystal showed an average value of 6×10^4 cm^{-2} in the center portion of the crystal. Growth of large diameter wafers is important from the consideration of reducing production costs of devices.

Yoon Soo Park
ONRFE/AFOSRFE

DEFECT-FREE GaAs CRYSTALS

The Nippon Telegraph and Telephone Public Corporation (NTT) has announced the successful growth of defect-free GaAs single crystals of 5 cm in diameter by the LEC method at its Atsugi Electrical Communication Laboratory. The new growth technique to reduce dislocation density involves:

- the use of a thick B_2O_3 encapsulant so that the entire crystal is immersed in B_2O_3 liquid during the growth process,
- the addition of isoelectronic In impurities,
- application of the magnetic field.

Detailed technical information on growth procedures has not yet been released.

Yoon Soo Park
ONRFE/AFOSRFE

MARRIAGE OF MBE AND IMPLANTATION SYSTEMS

Both the Optoelectronics Joint Research Laboratory (OJRL) in Kawasaki and the Electrotechnical Laboratory (ETL) in Tsukuba have announced the construction of a novel system combining an MBE growth system and an ion implantation system. In the integrated system, OJRL employed a 100 keV focused ion beam (FIB) system with an Au-Si-Be liquid metal ion source for maskless ion implantation and patterning. The OJRL FIB system can focus ion beams down to smaller than 0.1 μm in diameter and is connected to the MBE system through the sample transfer chamber of ultrahigh vacuum ($\sim 5 \times 10^{-10}$ Torr). ETL utilized a conventional low energy (less than 50 keV) ion implanter for doping of various n- and p-type impurities. The integrated system at both OJRL and ETL are primarily directed toward research activities related to the realization of planar-type OEICs and are expected to have substantial impact on future OEIC fabrication processes.

Yoon Soo Park
ONRFE/AFOSRFE

A COMPARISON NOTE ON THE PERFORMANCE OF THE FUJITSU V-200 AND THE HITACHI S810/20 SUPERCOMPUTERS

Recent performance data of the new Japanese supercomputers on the Livermore loops benchmarks shows an average of about 100 Mflops on Hitachi's S810/20 supercomputer and about 133 Mflops on Fujitsu's VP-200. This may be compared to the CRAY X-MP's average of 68.6 Mflops (using version 1.13 of the CFT CRAY Fortran compiler). In this note, I shall summarize some of the conclusions derived from my benchmark tests; a more thorough discussion of results will be presented elsewhere. The results of the benchmarks appear to be consistent with the Livermore data concerning vector performance. However, the benchmark results imply that other important characteristics of these machines, notably scalar performance, is not readily inferred from the Livermore data alone. My observations suggest that the two Japanese machines have somewhat similar vector capabilities but that their scalar capabilities are quite different. The Fujitsu VP-200 appears to have scalar capabilities similar to those of the CRAY X-MP while the Hitachi S810/20 appears to run in scalar mode at significantly lower speeds. Since most applications codes include portions which cannot be vectorized, this conclusion implies that the performance of the VP-200 and S810/20 on a given application code may be quite different.

The hardware of the Japanese supercomputers allow, in both cases, memory configurations of up to 256 MB. However, the maximum memory capacity which has been delivered so far is 64 MB; for example, the S810/20 at Tokyo University. While the vector registers of these two Japanese supercomputers have the same capacity of 64 KB, the VP-200's compiler can rearrange its vector register into multiple possible configurations ranging from 256 vector registers with 32 elements to 8 vector registers with 1024 elements. In contrast the 64 KB of the S810/20 vector registers are arranged into a fixed configuration, 32 registers with 256 elements each. The reconfiguring capability of the VP-200 should give this machine an advantage in computations with long vector but this is a hypothesis which I have not yet tested. It also remains unclear how the S810/20's semiconductor extended memory (256 MB at Tokyo University) compares with the VP-200's parallel I/O capability.

The architecture of each machine includes a scalar and a vector unit. However, their clock cycles are quite different; the vector unit of the VP-200 runs at 7.5 nsec; while that of the S810/20 at 14 nsec; their scalar units run at 15 nsec and 28 nsec, respectively. The

Hitachi machine bandwith from memory was recently upgraded to 64 bytes every clock cycle, the same memory bandwith of the VP-200. The S810/20's clock rate is thus about half of the VP-200. This disadvantage can be offset, in programs with high vectorization ratios, by the thoroughput yielded by the S810/20's twelve pipelines which number twice those of the VP-200. Both Hitachi and Fujitsu have used modifications of their most powerful general purpose machines (Hitachi; its M280H, and Fujitsu; its M380) as scalar units for their supercomputers. It has been claimed that the M380 is the fastest scalar machine in the world; and its average performance on the Livermore loops is 9.00 Mflops as opposed to the M280H's 6.61 Mflops. Thus, the VP-200's superior scalar performance on my benchmarks can be traced back to the M380's edge over the M280H. As noted above, the impact of this advantage of the VP-200 will become more pronounced as the vectorization ratio of the application code deviates from the perfect vectorization ratio of 1:0.

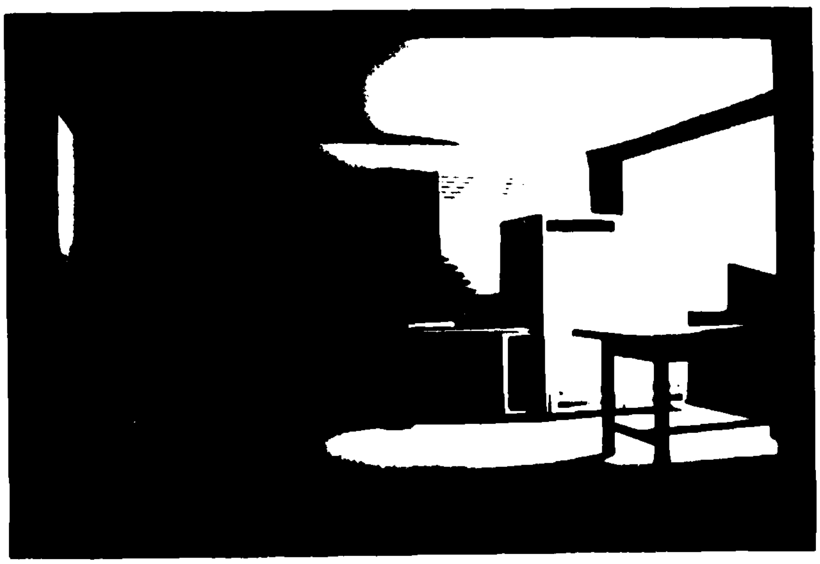
Concerning software, I am not yet in a position to make a meaningful comparison, but I have been impressed by Fujitsu's massive R&D effort to make the VP-200 a user friendly supercomputer. In future work, I shall compare the tuning tools provided by both supercomputers systems.

Raul Mendez
New York University

COMPUTER GRAPHICS AT HIROSHIMA UNIVERSITY

One of the more active Asian projects in computer graphics is the one directed by Professor Eihachiro Nakamae (Electric Machinery Laboratory, Hiroshima University, Higashihiroshima 724). Nakamae's work is already remarkable for its applications in several areas.

A favorite computer graphic demonstration is for the system to make a picture of itself; a couple of years ago beautiful patterns of the Cray computer were widely distributed. Some generated pictures, however, despite their perfection of shading, texture, and perspective, still look a little unrealistic because of the shadow depiction. The example below, which shows the computer room in Nakamae's laboratory, is a very realistic image indeed. In fact, most observers cannot believe that the original is not a real photograph.



An important factor in obtaining such realism is the ability to calculate illuminance components from area and polyhedron light sources. In the example shown, the light apparently comes from the uniformly bright window. Umbral and penumbral illuminances must, of course, take into account the fact that the areal light is interrupted by intervening objects; also, reflectances may have to be considered. Nakamae already has programs that can handle two rectangular light sources, such as a window and a ceiling fixture. One linear and one point light source can also be included in the same scene.

Hiroshima has experienced a postwar building boom, and some of Nakamae's methods have been applied in the evaluation of new building proposals. On a main avenue, for example, developers wanted to erect a large high-rise hotel; not only was Nakamae able to produce a realistic picture of what the street would look like if the large building were to be constructed, but also to show how the shadows would appear on all the surrounding buildings, at each hour of the day. The computer screen "walks" through the day. This kind of dynamic display may soon be an accepted part of the environmental impact evaluation of large construction projects.

Other applications at Hiroshima University include three-dimensional depiction of magnetic flux lines in electrical coils, and the realistic display of sections in biological tissue. A fairly spectacular example of anatomical work starts with the contour lines in successive sections through a mouse embryo; finally, the contours are connected and modeled to yield a semitransparent stereographic display. The impression of depth is striking; and such semitransparencies can also be beautifully colored by the computer, to suit the taste or the application.

Nicholas A. Bond, Jr.
ONRFE/AFOSRFE

CANCER RISK FACTORS

Health surveys around the world usually show that smoking increases the likelihood of lung cancer and other disease. A recent follow up study in Japan also indicted smoking; it was unusual for its large sample size, relatively long follow up period, and the apparent effect of protective dietary factors.

Back in 1965, the Japanese National Cancer Center collected life style information from over 122,000 healthy men over 39 years of age. Subjects described their smoking and dietary habits. By 1981, nearly thirty thousand of the original cohort had died with some eight thousand of the deaths attributed to cancer. Center investigators tabulated the official death causes against the original life style questionnare responses. The highest risk level, which was given a score of 100, was found in habitual smokers and drinkers who regularly eat meat but did not claim to eat vegetables every day. If a habitual smoking and drinking respondent claimed to eat vegetables daily, the risk score dropped to 40. Thus on a simple *post hoc* basis, vegetable intake may confer some cancer protection, even to the person who smokes and drinks.

Reported habitual smoking was correlated more strongly with cancer risks than was drinking behavior; in fact, habitual drinking by itself did not change risk levels very much, but when it was combined with smoking and "no daily vegetable" intake, it worsened the risk. At the positive or preventive end, the data suggested some radical reductions in risk; thus, for those men claiming the best pattern (no smoking, no drinking, daily vegetable intake), liver cancer risk was 28 and lung cancer risk was down to seven. Stomach cancer

risk, which is regarded as being especially high in Japan, was only half as great in the best habits group.

Nicholas A. Bond, Jr.
ONRFE/AFOSRFE

SIXTEEN KILOBIT GaAs MEMORY

Nippon Telegraph and Telephone (NTT) announced in September 1984 the successful testing of a 16 Kb static random-access memory chip (S-RAM). This chip is believed to be the first gallium arsenide (GaAs) chip with 16 Kb capability; it is a follow on to the NTT 4 Kb chip which was produced last winter.

NTT reports that the chip has about 100,000 field effect transistors, that it is about 7 mm x 6 mm in size, and that its performance parameters compare favorably with those of silicon 16 K S-RAMs, as follows:

	New GaAs Chip	Silicon Bipolar Chip	Silicon Metal Oxide Chip
Address Access Time	4.1 ns	15 ns	24 ns
Power	1.5 W	.75 W	.58 W

NTT is certainly now working toward a 64 K GaAs S-RAM; no specific time predictions have been made for that item. The new 16 K GaAs chip is in a "trial manufacture" state and is not yet on sale.

Nicholas A. Bond, Jr.
ONRFE/AFOSRFE

CHINESE CHARACTER KEYBOARDS - THE RACE HEATS UP

IBM's recent announcement of a new sales effort in the People's Republic of China shows again the importance of kanji or the "Chinese character" entry problem for computers. The problem is a daunting one, of course, because of the thousands of kanji characters themselves, because a single character or ideograph can be composed of many strokes, and because many characters sound exactly alike which makes strict homonymic entry impossible.

IBM's system groups characters according to a (relatively) few radicals inside each group; a stroke count can provide further discrimination. To close in on the desired character, the machine displays the possibles, given the input specifications up to that point, and a final keyboard entry chooses one character from the set of possibles. It sounds slow and complicated, but skilled operators reportedly can approach an entry rate on the order of a character per second. There are several other proposals including one that uses Romanized syllabary of spoken Chinese sounds, and various letter coding systems which require initial memorization of a special table.

For Japanese sets of kanji characters, where only a few thousand are needed, the fastest keyboard right now is probably Professor Hisao Yamada's Superwriter II. Yamada (Tokyo University) ignores mnemonic and other associative devices and concentrates on producing an eventual, smooth two-stroke entry after several hundred hours of practice.

Yamada's code tables are overlearned in the same way that English keyboards are unconsciously known by skilled Western typists. Yamada has preliminary evidence which shows that a skilled Japanese kanji operator, using his system, can produce input rates of up to 200 strokes (100 characters) per minute. This result, which seems almost unbelievable at first glance, will receive more intensive analysis as the keyboard race continues.

The new keyboards now being marketed for Chinese character entry work should provide some interesting testbeds for experiments on typing. Recent American research has shown that a simple-minded "chunking" model is wrong; that is, as a typist becomes skilled, the material is not just organized and stored as meaningful units or "chunks," and then emitted as separate little pockets or bursts of behavior. Indeed, there can be cognitive elements (such as awareness of errors) right in the middle of a "chunk" unit. It may turn out that, under appropriate keyboard and training conditions, typing rates for Chinese and English are about the same despite the surface complexity of the Chinese ideographic notation.

Nicholas A. Bond, Jr.
ONRFE/AFOSRFE

CLINICAL ANALYSIS OF SPEECH FREQUENCIES BY TELEPHONE

Yokohama Municipal Cancer Detection Center is now operating a computer-aided system for the early detection of laryngeal cancer. Since hoarseness of speech is a fairly reliable precursor of that disease, Dr. Masafumi Suzuki and his team tried a phone-in system for the analysis of suspected cases. It was not known how effective the computer analysis of phone-in voice signals would be, as the real speech band is considerably clipped and distorted when sent over phone lines.

An initial sample of 1276 school teachers was used for feasibility-study purposes; a signal analysis which utilized frequency and variance parameter estimates scored each person's input. Some 120 of the callers in sample had voice profiles resembling those of throat cancer victims. Upon examination, none of these 120 selected people actually had cancer; but 50 had polyps in the vocal cord--information of clinical significance to the patient. The free analysis service will continue, with each call-in patient being asked to pronounce Japanese vowels. Results are returned to the caller within three weeks, and more sophisticated discriminant functions will be utilized as more experience is gained with the system.

Tsugio Satoh
ONRFE/AFOSRFE

A SURVEY ON SEMICONDUCTOR RESEARCH IN JAPANESE UNIVERSITIES: LABORATORY VISITS (I)

Yoon Soo Park

INTRODUCTION

This report surveys some of the research and development activities in the area of semiconductors with particular emphasis on III-V compound semiconductor materials, characterization, processing and devices, being carried out at a number of Japanese university laboratories. Accounts of each laboratory are based on observations made by the author and technical discussions held during laboratory visits.

In general, the university laboratories visited were well supplied with new as well as old equipment providing the basis for strong research programs of both basic and applied natures. The research staffs and students were highly motivated and seemed to pursue their work with uncustomary enthusiasm. The projects, in general, had well-defined goals. Renovation activities and the replacement or upgrading of old equipment were noticed in many laboratories. These activities may reflect the increased research support from the Japanese government stemming from recent emphasis on and concern with the creative and basic aspects of the science and technology programs of universities and industrial R&D establishments.

Throughout the R&D community, the development patterns of Japanese science and technology are changing. The generalization that the Japanese accept or import knowledge, study it thoroughly, refine it and convert it into a product instead of seeking to discover original, far-reaching concepts themselves is no longer an appropriate description of Japan's present research and development efforts.

Exploratory and creative research projects are being strongly promoted within university laboratories. For example, to investigate the new field of nanometer structure electronics, the Ministry of Education, Science and Culture (MESC), which is primarily responsible for promoting basic research at the universities, in 1982 initiated a national project, "Nanometer Structure Electronics," involving five key universities (Osaka, Kyoto, Tokyo, Tohoku, and Tokyo Institute of Technology) with an annual budget of 100 million yen (see Osaka University--Namba Laboratory in this report). For materials and device research, many university laboratories now have, or are installing, either MBE or MOCVD growth systems or both, which had previously been considered prohibitive. As a result, work on novel device structures of quantum wells and superlattices, which was once monopolized by big industrial device houses, is now being intensively pursued at the universities.

Unlike industrial visits, these visits were conducted in an informal fashion; discussions were frank and open, and laboratory tours were freely given. This report attempts to disclose the scope of the laboratories, their current research activities and experimental facilities, and to summarize their recent accomplishments. Not all the laboratories visited are included due to insufficient data. Clearly, the Japanese university laboratories have taken a leadership position in several areas of research putting them in the forefront of scientific progress.

LABORATORY VISITS

- Institute of Industrial Science
  University of Tokyo
  Roppongi, Minato-ku
  Tokyo 106

  - Professor Toshiaki Ikoma--Ikoma Laboratory

    Research Activities--General

    Materials and Processing

    - LPE growth of InP and InGaAsP
    - reaction of metals with GaAs and InGaAsP

    Characterization

    - DLTS and optical DLTS
    - photocurrent mapping
    - photocapacitance spectroscopy
    - low temperature photoluminescence
    - V-I and C-V
    - admittance spectroscopy
    - scanning electron microscopy and electron microscopy and electron beam acoustic microscopy

    Devices

    - computer-aided analysis and design of new devices
    - novel switching devices
    - novel lasers
    - ZnO varistor
    - electrochromic devices

    Current Research Emphasis

    - LPE growth of multilayers of InP and InGaAsP systems for novel laser application
    - silicide and noble metal Schottky barrier formation for GaAs and InP and interface characterization
    - characterization of semi-insulating GaAs crystals
    - DX centers in visible laser
    - surface defects introduced by dry processing
    - development of electron beam acoustic microscope
    - two-dimensional analysis of novel semiconductor devices
    - conduction mechanism and reliability of ZnO

Observations

Professor Ikoma is a recognized authority in the use of DLTS in Japan and, in particular, his work on interpretation and identification of the midgap "EL2" centers in

GaAs is well-recognized throughout the international scientific community. It has been established that the midgap electron traps, such as EL2, play an important role in the compensation of semi-insulating GaAs substrate materials. Recently, Professor Ikoma has shown that the deep donor level EL2 cannot be considered as a single level, and has introduced the concept of the "EL2 family." His interpretation is based on the observation that there existed a variety of midgap levels that showed scattered capture cross sections, a thermal instability for thermal annealing, and photoquenching effects with different efficiency spectra in LEC, HB, VPE and O-implanted LPE GaAs crystals. By studying the transistions between the normal state and the metastable state of the midgap level with photocapacitance transients and from the experimental results on photoquenching spectra, he has concluded that the midgap levels of the "EL2 family" found in GaAs have various electron lattice couplings and may be due to arsenic aggregates having amorphous-like atomic structures.

Professor Ikoma is also making extensive use of the electron beam acoustic microscope (EAM) for characterization and diagnosis of semiconductor materials devices and integrated circuits. A subsurface structure, which is difficult to observe using conventional optical and scanning electron microscope, can easily be examined by the EAM.

- University of Tokyo
  Faculty of Engineering
  Department of Electronic Engineering
  7-3-1 Hongo, Bunkyo-ku, Tokyo 113

  . Professor Takuo Sugano

    Research Activities--General

      Materials and processing

        . anodization of GaAs and InP in oxygen plasma

      Characterization

        . deep level transient spectroscopy (DLTS) for dielectric-III-V semiconductor systems
        . theoretical study on energy band structure of ternary alloys

      Devices

        . InP MIS field effect transistors

      Current Research Emphasis

        . fabrication of InP MISFET by anodization of Al-InP systems in oxygen plasma and by evaporation of SiO_2 onto InP substrates

    Observations

In addition to the research activities involving compound semiconductors as depicted above, Professor Sugano and his team are actively engaged in the research and development of the Si MOSFETs and Josephson junction technologies.

His team has been actively pursuing anodization of GaAs in oxygen plasma for the past ten years. However, since the density of surface states at the oxide film-GaAs interface was too high ($\sim 10^{13}$ cm^{-2}), efforts on GaAs MOSFETs were transferred to InP MISFETs. For InP MISFETs fabrication, his team is taking three approaches:

- using plasma anodic Al_2O_3 as the gate insulator,
- with plasma anodic Al_2O_3 and an interlayed native oxide gate insulator, and
- using plasma anodization of α-Si:H_2.

In the three approaches, particular attention has been paid to reduce long-term drift of the drain voltage-current characteristics.

For the InP MISFETs with plasma anodic Al_2O_3 and an interlayed native oxide gate, a native oxide layer is grown on the InP substrates by plasma anodic oxidation before an aluminum film is deposited. From the MHz C-V characteristics for MIS diode using an n-type substrate annealed at 350°C, the minimum density of surface states was deduced to be $\sim 3\times10^{11}$ cm^{-2} eV^{-1}. The InP MISFETs fabricated on semi-insulating, Fe-doped, (100) substrates, showed the effective mobility and the threshold voltage of 2100-2600 cm^2/V.s and -0.3-(-0.9) V at 300°K, respectively. For the period of 5 μ sec-5×10^4 sec, the variation of the drain current was found to be within ±4%.

An Al-SiO_2-InP MIS structure fabricated on InP substrates by plasma anodization of amorphous silicon exhibited a sharper oxide-semiconductor interface than that of a plasma anode Al_2O_3-InP structure; however, the effective electron mobility of the device was small. Currently, the team is trying to increase the mobility by improving the process conditions.

Professor Sugano has a collaborative InP MISFET program with Professor H. H. Wieder of the University of California at San Diego and Professor C. Wilmsen of Colorado State University in Fort Collins under the joint auspices of the National Science Foundation of the United States and the Japan Society for the Promotion of Science.

The current research activities also include the investigation of the deep levels in InP annealed with a Q-switched ruby laser and/or furnace heating.

. Professor Takeshi Kamiya

Research Activities--General

Characterization

. radiation and nonradiative processes in AlGaAs/GaAs and InGaAsP/InP heterostructure crystals

. compensation mechanisms in high-resistive GaAs, especially in relation to GaAs ICs

. fast optical phenomena in semiconductors for optoelectronic information processing

Devices

- semiconductor lasers and light emitting diodes
- GaAs MESFETs and their integration
- optoelectronic integration based on InP- or GaAs-related materials.

Current Research Emphasis

- carrier density dependent lifetime determination using photoluminescence phase shift method and pulse decay method
- analysis of output-nonlinearity and temperature characteristics of InGaAsP/InP semiconductor lasers and light emitting diodes
- control of characteristics of semiconductor lasers (coherence control by multielectrode structures, mode stabilization by coupled cavity structures, short pulse generation by mode-locking, etc.)
- correlation between GaAs MESFET characteristics and the properties of semi-insulating GaAs substrates (especially backgating effect)

Observations

Professor Kamiya and his graduate students are engaged in research activities aimed at obtaining a fundamental understanding of optical and electronic semiconductor devices which would contribute toward the achievement of their integration in optoelectronic integrated circuits (OEIC).

His recent contributions include the development of a multimode laser theory to clarify the relationship between the waveguide structure and the mode characteristics, both axial and lateral, experimental and theoretical investigations of carrier density dependent lifetime, and output nonlinearity of InGaAsP LEDs, and the measurement of carrier lifetime in InGaAsP/InP double heterostructure crystals by the photoluminescence phase shift method to interpret the output nonlinearity and temperature sensitivity of LEDs.

Dr. Kamiya is also investigating the backgating effect between neighboring MESFET devices on semi-insulating GaAs substrates. The backgating effect is one of the possible limitations in the attainment of high density, large-scale integration of GaAs ICs. He formulated a device model for an ion-implanted GaAs MESFET taking into account compensation mechanisms in semi-insulating substrates. In this model, material parameters characterizing the substrate compensation determine the space charge density at the n-i junction region, and the modulation of basic FET characteristics by the backgate bias can be evaluated numerically. The model suggests that close compensation of EL2 and Cr is desirable to reduce the backgating.

- Kyoto University

Department of Electrical Engineering
Kyoto University
Kyoto 606

- Professor Akio Sasaki
  Dr. Shigeo Fujita
  Dr. Yoshikazu Takeda

Research Activities--General

Materials and processing

- LPE growth of InGaAs/InP
- LPE growth of InGaAsP/InP
- LPE growth of AlGaSb/GaSb
- OMVPE growth of ZnS and ZnSe on GaAs or GaP
- growth of GaAsP by iodine transport
- growth of ZnS by iodine transport
- plasma-enhanced CVD of silicon nitride

Characterization

- Hall effect measurements at 4.2-400°K
- photoluminescence at 4.2-300°K
- cathode luminescence
- x-ray diffraction
- phase contrast optical microscopy
- C-V and I-V measurement
- DLTS
- electron microscopy
- EBIC measurement
- ellipsometry
- Auger electron spectroscopy

Devices

- InP/InGaAs Schottky photodiodes
- InP/InGaAsP HJBTs
- InP/InGaAsP HPT
- InP/InGaAsP light amplifiers
- InP/InGaAsP optical multifunction
- ZnS MIS LEDs
- GaAsP solar cells
- AlGaSb solar cells

Current Research Emphasis

- preparation and characterization of electrical and optical properties of III-V alloy semiconductors such as InGaAs, InGaAsP and AlGa(As)Sb
- OMVPE growth and optical properties of II-VI compounds such as ZnS and ZnSe
- device physics and electronics of blue LEDs, phototransistors, light amplifiers, optical bistable devices, solar cells, and high-speed devices

Observations

Professor Sasaki's interests encompasses a wide range of materials, devices and characterization activities as summarized above, but he places special emphasis on preparation, processing, device physics and electronics of alloyed semiconductors.

In the laboratory very intensive efforts are expended in the preparation of hydrogen-free or stable silicon nitride films useful for final passivation or interlayer insulation in VLSI chips, because hydrogen atoms incorporated in silicon nitride produced by plasma-enhanced chemical vapor deposition are believed to cause various instabilities in VLSI chips. Instead of producing the silicon nitride films from the reactive plasma of SiH_4 and NH_3 as has been done conventionally, they are preparing the plasma CVD of silicon nitride from a SiF_2, N_2, and H_2 gas mixture. As compared with the silicon nitride deposited from SiH_4-NH_3, they find that the film exhibited higher resistivity and breakdown strength and that the hydrogen bondings in the film remained stable against thermal treatment. Because of the higher reactivity of the SiF_2 gas as compared to a SiF_4 gas, the films can be deposited at the higher deposition rate for the same N/Si ratio with more nitrogen, and less fluorine and oxygen and without H_2 gas. Since the films deposited without H_2 gas do not contain hydrogen atoms, they expect that device instability caused by hydrogen diffusion in the passivation can be eliminated.

There are strong growth activities of InGaAs and InGaAsP on InP by LPE for various optoelectronic devices. To achieve highly doped p-type layers with an abrupt doping profile in InGaAs, Mg doping has been tried since Mg has a low diffusion coefficient, a low vapor pressure, and a high distribution coefficient. However, because of the high affinity of Mg for oxygen, the surface of Mg-doped InGaAs tends to be decorated with MgO flakes which affects the uniform growth of successive layers. By adding Al and Mg simultaneously into the In-Ga-As melts, they were able to achieve MgO-free surfaces and p-type conducting with a hole concentration of 1.7×10^{18} cm^{-3} by adding an order of magnitude less Mg mole fraction in the liquid than without Al addition (6.3×10^{-6} *vs.* 2.5×10^{-5}). Al in the melt serves as a getter for oxygen and Al_2O_3 is more easily formed in the melt during the growth cycle.

The laboratory recently has fabricated a 1 μm wavelength region Ag/p-InP/p-InGaAs Schottky photodiode from a multilayer heterostructure of p-InGaAs/p-InP/InGaAs/InP using the selective etching of InP and InGaAsP. The P-InGaAs/p-InP structure in the multiple layer heterostructure was, in essence, inverted to the p-InP/p-InGaAs structure. The InP on top of InGaAs configuration was used to make use of the higher Schottky barrier of InP since the Schottky contact on InGaAs is leaky at room temperature. The inversion was also necessary because it is difficult to grow InP directly on InGaAs. At a reverse bias of -5 V, the responsivity of the diode in the wavelength range (0.92 μm $\le\lambda\le$ 1.65 μm) is higher than that at -1 V.

They have also fabricated a high gain, wavelength-selective heterojunction phototransistor (HPT) by adding an absorption layer to the wide bandgap emitter using the InGaAsP/InP material system. The HPT exhibited an optical gain as high as 400 at the spectral response peak wavelength of 1.2 μm with the spectral half-width of 53 nm under an incident light power Pin of 3.6 μW. The rise time of 18 μs was obtained at Pin=10 μW and the detectivity D* was estimated to be 3.7×10^{10} cm $Hz^{1/2}$/W at a frequency of 2 kHz under an optical bias level of 0.1 μW. In the present scheme, the peak wavelength of the HPT can be adjusted from the absorption edge of InP (0.92 μm) to that of $In_{0.47}Ga_{0.53}As$ (1.65 μm).

Another very interesting, impressive optoelectronic integrated device with light amplification and optical bistability was demonstrated using the InP and InGaAsP alloy semiconductor system. In this device, a double heterojunction light-emitting diode is integrated onto the collector portion of a heterojunction phototransistor. The device exhibits light amplification, optical bistability, light-activated switching and unidirectionality.

- Osaka University
  Laboratory of Solid State Electronics and Microfabrication Research Laboratory
  Faculty of Engineering Science
  Toyonaka, Osaka 560

  . Professor Susumu Namba
    Associate Professor Kenji Gamo
    Dr. Mikio Takai

Research Activities--General

Materials and processing

- recrystallization process of ion-implanted semiconductor layers by furnace and laser annealing
- growth of semiconductors on insulating substrates such as SOI by zone melting with laser or strip line heater
- electron beam, x-ray and ion beam lithographies
- sputter and ion beam etchings
- ion implantation and annealing
- focused ion beam technology
- dry processing
- maskless processing

Characterization

- electrical and optical characterizations of the effects of various beam processings on semiconductors
- analysis of composition, impurity and crystalline states in semiconductor bulk, interface and surface by Rutherford backscattering channeling and proton induced x-ray emission (PIXE) measurements

Current Research Emphasis

- selective growth of single crystalline Ge islands on SiO_2 (by the zone melting technique using a strip line heater) for use as a substrate for MBE growth of GaAs and related compounds
- growth of InSb layers directly on insulating substrates by the zone melting technique for photoelectronic device applications
- characterization of deep levels associated with defects induced in GaAs and InP by electron, proton and heavy ion irradiations by means of DLTS, OTCS (optical transient current spectroscopy) and photoconductivity measurements

Observations

The Laboratory of Solid State Electronics and the Microfabrication Research Laboratory at Osaka University is headed by Professor Namba who is also serving as head of the Laser Science Group at the Institute of Physical and Chemical Research (Rikagaku Kenkyusho) located in Wako-shi, Saitama. Professor Namba is well-known for his work in ion implantation and various semiconductor process technologies.

One of the very interesting research activities observed at the laboratory was the activity related to the MBE growth of GaAs layers on single crystal Ge islands-on-insulator. To realize GaAs-on-insulator (GaAs SOI), the laboratory has succeeded in growing single crystalline Ge islands with (100) orientation on insulating substrates (SiO_2/Si) by zone melting with graphite strip heaters.

Two very interesting types of geometrical patterns for Ge islands were used. One of the patterns consists of a series of 100x80 μm rectangles with sides connected to a narrow, 30x10 μm stripe which selects and transfers a single grain orientation during melt zone movement and suppresses sub-boundary formation in the connected islands. The second type is a series of isolated 250x100 μm rectangles with a peaked side. A single crystal grows from the peak side as a self-seed and the melt zone is moved from this side. The Ge islands grown after zone melting were found to be single crystals with <100> orientations and had electron concentrations of 10^{16}-10^{18} cm^{-3} and Hall mobilities of $1\text{-}3\times10^3$ cm^2/V.s.

The GaAs layers grown by MBE on these islands were of good quality as evaluated by optical microscopy and photoluminescence. The layers exhibited photoluminescence spectra similar to those of GaAs layers grown on bulk Ge crystals, comparable in their intensities but shifting slightly in peak energies due to strain induced by the thermal expansion coefficients between Ge and GaAs.

In contrast to recent activities and advances made in silicon-on-insulator (SOI), very little work is available on SOI structures with III-V compound semiconductors. Recently there has been growing interest in the possibility of developing integrated circuits that combine GaAs and Si devices fabricated on a single monolithic GaAs/Si. In view of this interest, the GaAs SOI work at the Namba Laboratory is very encouraging. The approach taken at the Namba Laboratory is different from that taken by the Musashino Electrical Communication Laboratory, NTT, where they deposited Ge on a W-layer coated SiO_2 (Ge/W/SiO_2). The Namba Group claims it is not necessary to insert the W-layer for good growth of Ge if the SiO_2 is of high quality.

A great deal of activities in focused ion beam technology are detected in the laboratory. The laboratory is equipped with a 70 keV fine focused ion beam system, with liquid metal alloy ion sources for various ions. With the system, a variety of experiments in maskless ion implantation, etching, and scanning lithography are being conducted.

Recent accomplishments include:

- a grating pattern formed on the InP surface using a 35 keV focused Ga ion beam. These patterns were formed while directly scanning the beam without using a mask.

- maskless ion beam assisted etching of GaAs with 50 keV Au ion beam in a chlorine atmosphere at a pressure of 0.01-0.1 Torr. The etching rate was found to be 100 times faster than physical sputter etching.

The Microfabrication Research Laboratory is also exploring a new field, that of nanometer structure electronics--the future of microelectronics. The laboratory is the leading laboratory of the project on nanometer electronics sponsored by the Ministry of Education, Science and Culture. The project began in 1982 and is divided into five main subjects:

- a study on quantum mechanical effects and electronic processes in nanometer structures such as one- or two-dimensional conduction and quantum size effect,
- crystal growth and development of new devices with nanometer structures,
- material processing for nanometer structures,
- nanometer fabrication technology, and
- applications of nanometer electronics to ultrahigh density and high speed electronics, and medical and biological fields.

Under the project the laboratory has developed a 50 keV nanometer electron beam lithography using a TFE electron gun. The beam diameter of a few nanometers and the stable beam current with a fluctuation less than 1% have been obtained. To investigate one-dimensional conduction phenomena, 20-50 nm-wide fine structures in Si and Si MOS devices were fabricated. Currently, they are investigating an ultimate resolution of electron and ion beam lithography using this system.

- Osaka University
  Department of Electrical Engineering
  Faculty of Engineering Science
  Osaka University
  Toyonaka, Osaka 560

  - Professor Yoshihiro Hamakawa
    Associate Professor Taneo Nishino

    Research Activities--General

    Materials and processing

    - LPE growth of InGaAsP on InP or GaAs
    - MBE graphoepitaxy growth of large-area thin film GaAs

    Characterization

    - photoluminescence
    - electroreflectance
    - DLTS
    - excitation spectroscopy
    - time-resolved spectroscopy
    - Vidicon-mode characterization of semiconductor hetero and p-i-n junctions

    Devices

    - large-area, thin film GaAs solar cells grown by MBE graphoepitaxy
    - InGaAs/IInP photodetector

    Current Research Emphasis

    - optical characterization of deep impurities associated with 3d transistion metals in GaAs by photoluminescence spectroscopy

- luminescence, characterization of the interface in LPE grown InGaAs/InP heterojunctions
- MBE graphoepitaxy of large-area, thin film GaAs on noncrystalline substrates for solar cell use

Observations

Hamakawa Laboratory, headed by Professor Hamakawa, is world reknown because of the laboratory's contributions to the development of amorphous Si solar cells. Many research projects involving amorphous semiconductors are being conducted extensively in addition to the III-V compound semiconductor projects as outlined above. Projects on amorphous Si include:

- electronic processes in amorphous semiconductors,
- characterization of amorphous and microcrystalline silicon,
- device physics analysis of α-Si photovoltaic cells, and
- trials for high efficiency α-Si basis solar cells.

Besides the Si and III-V works, they are also conducting research on preparation of PLZT ferroelectric thin films for electro-optic and photochromic applications, and on $PbTiO_3$ films for pyroelectric infrared sensors and ultrasonic sensors. There are efforts on the development of thin film electroluminescent devices.

Strong emphasis is being placed on photoluminescence characterization of impurities and defects in semiconductors. The laboratory is heavily involved with the identification of deep acceptors due to three-dimension transition metals such as Cr, Mn, Fe, Ni, and Cu in GaAs. Transition metals in GaAs act as compensators for residual shallow donors, resulting in high resistivity. In the GaAs samples doped with Cr, Fe or Ni, sharp no-phonon intercenter emission lines are observed in the near-infrared region at 4.2 K. These characteristic emission lines are interpreted in terms of intercenter transistions between d-electron levels split by the crystal field of the GaAs lattice. The well-known deep emission line at 0.839 eV in Cr-doped GaAs is interpreted in terms of a Cr-V_{as} (arsenic vacancy) complex. The no-phonon line at 0.5490 eV in Ni-doped GaAs is attributed to intercenter transitions in Ni-S pairs.

A series of InGaAs layers nearly lattice matched to InP at room temperature, which can be used as photodetectors in the optical fiber communication system, were grown by LPE. They employed the photoluminescence (PL) technique to study the InGaAs/InP interface. They observed a new PL band at 0.69 eV at 77 K and attributed it as due to some interface defects introduced during the LPE growth resulting from the lattice mismatch between InGaAs and InP at the growth temperature.

In an attempt to grow large-area, thin film GaAs on noncrystalline substrates, a new epitaxial growth technique called molecular beam graphoepitaxy is being developed. They have initiated GaAs film growth on Ni and polymide replica substrates by MBE. Progress in this technique should be followed, and the success and perfection of the technique may add a new dimension to thin film growth activities for three-dimensional integration of semiconductor devices.

- Tokyo Institute of Technology
  Imaging Science and Engineering Laboratory
  Nagatsuda, Midori-ku
  Yokohama 227

. Professor Hiroshi Kukimoto
Dr. Masashi Mizuta
Research Activities--General

Materials and processing

- MOCVD growth of III-V compound semiconductors such as InGaP, InGaAsP, and InGaAlP
- MOCVD growth of ZnSe and ZnS
- growth of conducting ZnCdS phosphorus and films
- growth of α-Si_xC_{1-x}:H

Characterization

- study of deep levels by photoluminescence, capacitance spectroscopy, photoacoustic spectroscopy (PAS), etc.

Devices

- III-V optoelectronic devices
- II-VI display devices

Current Research Emphasis

- investigation of DX centers in AlGaAs
- growth of doped InGaP grown by GaAs MOCVD
- growth kinetics of AlGaAs
- MOCVD growth of ZnSe and ZnS
- low temperature glow-discharge deposition of α-SiC:H

Observations

Professor Kukimoto and his team are actively engaged in research on improvements of materials technologies for future solid state devices with emphasis on display devices. They have four MOCVD systems dedicated to the growth of various material systems. In addition to III-V materials and device programs, they have strong efforts in phosphors and thin films for display devices and panels utilizing ZnCdS and hydrogenated amorphous silicon-carbon alloys α-Si_xC_{1-x}:H (x=0.2-0.4).

There is a well-coordinated program between materials characterization and crystal growth. Strong emphasis is placed on the use of DLTS to improve material quality for device fabrication. An example of this feedback activity is seen in their recent work on identification of deep levels in InP grown by MOCVD. In undoped InP epitaxial layers grown by MCVD on undoped InP substrates, they observed an electron trap with an activation energy of 0.53 eV (MOE2) which appears under a specific growth condition of phosphorus overpressure. Recently they have fabricated an InP MESFET by MOCVD on a Fe-doped substrate. Although they have obtained good FET characteristics, a substantial looping phenomenon has been observed in the drain current-voltage characteristics. From a study of deep levels in undoped n-type MOCVD grown InP layers on Fe-doped substrates, they concluded that two types of electron traps, F_1 and F_2 levels generated by outdiffusion of Fe from the substrates, whose activation energies are 0.48 eV and 0.78 eV, respectively, are responsible for the looping phenomena.

In a search for visible LEDs and heterojunction laser diodes, InGaAsP quaternary alloys lattice-matched to GaAs are being grown by low-pressure MOCVD. They have grown for the first time, $In_{1-x}Ga_xAs_yP_{1-y}$ layers in the composition range ($0.5 \leq x \leq .9$, $0 \leq y \leq 0.55$) using triethylindium (TEIn), triethylgallium (TEGa), arsine (AsH_3) and phosphine (PH_3) as source materials. The bandgap energies of the grown layers ranged from 1.6 to 1.9 eV. Good surface morphology and photoluminescence at room temperature were observed.

Low pressure MOCVD growth of InGaAsP/InGaP double heterostructures on GaAs for laser applications is also being pursued actively in the laboratory. This system is expected to cover the lasing wavelength region from 0.73 to 0.87 μm. The double heterostructure consists of 0.13 μm thick $In_{1-x}Ga_xAs_yP_{1-x}$ ($x \sim 0.7$, $y \sim 0.4$, Eg=1.76 eV) active layer sandwiched between two 0.8 μm thick $In_{1-x}Ga_xP$ ($x \sim 0.5$) cladding layers. With this structure, they observed stimulated emission under optical pumping both at room temperature and 150 K.

To produce highly doped InGaP, they employed H_2Se and dimethyl zinc (DMZn) as n- and p-type doping sources, respectively. They have achieved reproducibly n-type layers of 10^{8}-10^{9} cm^{-3} and p-type layers of 10^{17}-10^{19} cm^{-3} on Cr-doped GaAs (100) and Si-doped GaAs (100) by low pressure (75 Torr) MOCVD. Doping efficiency of both Se and Zn decreased with increasing growth temperature. InGaP p-n diodes fabricated exhibited electroluminescence peaking at 1.85 eV at room temperature.

Besides III-V work, there is an effort to grow high quality ZnSe films by MOCVD at low temperature. In the conventional MOCVD growth of ZnSe using DMZn and hydrogen selenide (H_2Se) sources, a parasitic reaction is usually taking place. By using DMZn and dethylselenide (DESe) as source materials, they have prevented this undesirable, premature reaction and obtained highly uniform, specular films of ZnSe on (100) GaAs at 469°C under atmospheric pressure.

Other noteworthy work ongoing at the laboratory is the work on the hydrogenated amorphous silicon-carbon alloy, α-Si_xC_{1-x}:H. This material system has been considered as a potential material for light emitting devices. Its photoluminescence covers the wide range of the visible wavelengths with a change in composition with a reasonable efficiency and short decay time ($\sim$200 psec) at room temperature. Recently, they have prepared α-Si_xC_{1-x}:H films by the glow discharge deposition of tetramethylsilane (TMS) and observed visible (white) electroluminescence at room temperature in the layer sandwiched between two insulating layers of Y_2O_3 when driven by ac voltages higher than 100 V. Their goal is to achieve flat display panels by fabricating light emitting layers onto suitable Si integrated circuits.

Another remarkable accomplishment obtained is the demonstration of the quantum size effect in amorphous QW heterostructures consisting of an ultrathin α-Si:H layer sandwiched between two α-$Si_{0.2}C_{0.8}$:H layers. In the optical absorption spectra for QW samples of different well widths, they observed an increase in optical energy gap at a well width of around 50 A, reflecting the quantization in the well. The width of 50 A as an onset of quantization is much narrower than that for the crystalline semiconductors (e.g., for the GaAs/GaAlAs system, the width is about 200 A). This quantum size effect was explained in terms of the quantization of holes in the valence band of α-Si:H confined by the potential walls of barrier layers.

- Tokyo Institute of Technology
  Department of Physical Electronics
  2-12-1, Ohokayama
  Meguro-ku, Tokyo 152

  . Professor Kiyoshi Takahashi
    Associate Professor Makoto Kanagai

Research Activities--General

Materials and Processing

. crystal growth of III-V (GaAs, AlGaAs) and II-VI (ZnSe) compound semiconductors by MBE, MO-MBE, photochemical CVD and LPE techniques

Characterization

. characterization of compound semiconductors by Hall effect measurement, DLTS, RHEED, PL, and SIMS analysis

Devices

. AlGaAs/GaAs high efficiency solar cells
. optoelectronic devices
. low threshold voltage ZnSe:Mn dc operated EL devices
. amorphous Si solar cells
. α-Si sensing devices

Current Research Emphasis

. MO-MBE of GaAs and AlGaAs
. ZnSe thin film electroluminesence devices by MBE
. photo-MOCVD of ZnSe
. photochemical vapor deposition of α-Si

Observations

Professor Takahashi's laboratory is employing a variety of crystal growth techniques in their pursuit for perfecting materials and device technologies. Professor Takahashi is well-known for his pioneering contributions to the development of MBE technology in Japan. He is an editor of the book, *Molecular Beam Epitaxy*, written in Japanese which has become a standard textbook on MBE in Japanese laboratories.

To overcome some of the disadvantages encountered in the conventional MBE technique, the laboratory is pursuing the metal organic molecular beam epitaxial (MO-MBE) growth of GaAs using trimethylgallium (TMG) and elemental arsenic (As_4) as sources in the MBE system. Recently they have grown mirror-like monocrystalline epitaxial layers of GaAs using the TMG-As_4 system on (100) Cr-doped GaAs substrates covered with narrow stripe patterns of SiO_2. Conductivity of the layers were p-type with carrier concentrations of 10^{18}-10^{19} cm^{-3} due to residual carbon impurities. However, they expect to reduce the carrier concentration by introducing H_2 ion beam or by using triethylgallium (TEG) as a gallium source instead of TMG. In particular, in contrast with the conventional MBE or MOCVD techniques, no deposition was observed on a SiO_2

film. This remarkable selectivity of crystal growth is believed to be due to the surface catalyzed growth process and is an important step toward the fabrication of GaAs integrated circuits in the MBE and MOCVD systems.

In the area of display devices, they are actively engaged in the research activities of developing low threshold voltage ZnSe:Mn El cells by MBE. For the Au/ZnSe:Mn/n-GaAs EL cells, the threshold voltage of as low as 3.8 V with the maximum brightness of 250 fl. has been observed. This is the lowest threshold voltage ever reported.

Another growth technique being pursued by the laboratory is that of photoenhanced MOCVD (photo-MOCVD). Recently, they have grown ZnSe films by photo-MOCVD employing UV and observed the effect of the UV irradiation on the growth rate and crystal structure of the ZnSe films. [For the ZnSe film growth, they employed diethylzine (DEZ) and dimethylselenide (DMSe) as sources]. In the nonirradiation condition, no deposition of ZnSe films on GaAs (100) substrates occurred below 350°C. When the substrates were irradiated with the UV light from a low pressure mercury lamp (2537 Å or 1849 Å), however, the deposition of ZnSe films occurred at lower temperature and an enhancement of the growth rate was observed. Even at the substrate temperature of 150°C, polycrystalline films were obtained. In the ZnSe films on glass substrates at 400°C deposited by the photo-MOCVD, the near-hand edge emission at 4500 A was observed at 77 K.

RECENT ACCOMPLISHMENTS IN SEMICONDUCTOR RESEARCH IN JAPAN AS SEEN AT THE 16TH CONFERENCE ON SOLID STATE DEVICES AND MATERIALS

Yoon Soo Park

INTRODUCTION

Japan's efforts to develop a high technology society were vividly reflected at the 16th Conference on Solid State Devices and Materials which was held in Kobe on 30 August-1 September 1984, under the auspices of the Japan Society of Applied Physics. The conference is held annually on a domestic level in Japan and every other year it is organized on an international scale to draw scientists from overseas. This year's meeting is the fifth international conference since the one held in 1982. The purpose of the conference is to bring together a number of the scientists and engineers who are actively involved at the forefront of solid state devices and materials development to discuss a wide range of topics.

There were about 840 participants representing 14 countries. There were 85 registrants from abroad including 43 from the United States, eight from the U.S.S.R., seven from the People's Republic of China, seven from West Germany and five from France. A total of 143 contributed papers, 27 invited talks, and 48 late news items were presented in 44 sessions during the three-day meeting. There were three sessions on panel discussions in the evening of the second day of the meeting. Because of the unexpected increase in the number of contributed papers compared to previous years, the sessions had to be organized into four parallel sessions with the exception of the opening session. Of the total 170 regular papers (invited and contributed) presented, Japan contributed 133 papers, the United States 21, and other countries 16. Forty-three of the 48 late news papers were contributed by Japan. Four papers by U.S.S.R. scientists were presented in the late news sessions.

Topics presented in the meeting covered the latest developments in device physics, device characteristics, and material technologies. New phenomena and future prospects for development in devices and materials technologies were emphasized. Subjects presented are classified into the following technical sessions:

- opening session,
- process technology (I-VII),
- bulk crystal growth,
- small geometry devices (I, II),
- OEIC,
- semiconductor lasers (I, II),
- characterization (I-IV),
- Si LSI (I-IV),
- discrete devices,
- imaging devices,
- high speed heterodevices,
- HEMT LSI and MISFET,
- GaAs MESFET and LSI (I, II),
- new materials,
- silicon-on-insulator (I, II),
- amorphous silicon and thin film devices (I, II),
- detectors and other III-V semiconductor devices (I, II),

- superlattice and heterostructures,
- Josephson and bubble devices (I, II),
- thin film growth,
- MOCVD,
- late news.

In addition, there were three evening panel discussions on the topics of:

- lithography for future submicron devices fabrication,
- characterization and microanalysis of LSI device processes and materials,
- GaAs LSI/VLSI.

Though the meeting was conducted in English and had an international flavor, it was truly a Japanese show in terms of both the number of the papers and the participants. Because of the size and the scope of the conference, instead of discussing the content of each paper presented and providing an overview of the various sessions, in this report an attempt will be made to present the highlights of the conference as judged by the author.

CONFERENCE HIGHLIGHTS

The conference was opened with a welcoming address given by Professor S. Namba, chairman of the organizing committee, in which he stressed the importance and role of materials and new materials for future development of solid state devices.

- Photomolecular Layer Epitaxy

In the opening session, J. Nishizawa of Tohoku University gave an invited talk on recent progress in low temperature photochemical processes. In his talk he stressed the importance and the role of photochemical processes in crystal growth and low temperature processes. With the irradiation of UV light, the crystal growth can be accelerated without defect generation at low temperatures. As an example, the photochemical-induced effects on the vapor phase epitaxial growth of GaAs layers (photoepitaxy) have been demonstrated. In the photoepitaxial growth of GaAs layers using a conventional $AsCl_3$-Ga-H_2 system, the 248 nm excimer laser was employed. With the light irradiation, the enhancement of growth rate was observed over the growth temperature range of 480-700°C. With an incident power of $\sim$1.7 W using the 248 nm laser, for example, the growth rate was increased by a factor of four. For the photoepitaxial layers grown with the irradiation of a high pressure mercury lamp, a 10-15% increase in mobility was observed.

Another example was given for GaAs layers grown using the combination of the photochemical process and molecular (atomic) layer epitaxy. This technique, called "photomolecular layer epitaxy," received a large amount of publicity in the Japanese news media prior to the conference. The technique, in essence, is the modification of the atomic layer epitaxy (ALE) technique developed by Tuomo Suntola of Lohja Corporation in Finland, who also gave an invited talk on ALE at the conference.

Dr. Nishizawa reported that 0.88 μm thick GaAs layers consisting of 3547 monolayers have been grown successfully at a substrate temperature from as low as 350°C through the repetition of alternative injections of TMG and AsH_3 source materials with irradiation of UV light from a Hg lamp or from an excimer laser in a ultrahigh vacuum system (5×10^{-10} mm Hg). AsH_3 was first admitted in the system with $p\approx5\times10^{-5}$ Torr for 20 sec, and then after a 1 sec long pause, TMG was introduced with 1×10^{-4} Torr ℓ/s for 4 sec.

The system used in the growth is shown in Figure 1. A halogen quartz IR lamp mounted above the sample was used to heat the substrate. Light 1 and Light 2 shown in the figure are UV sources from the Hg lamp and the excimer laser. Electrical data of the GaAs sample at 500°C showed p-type conductivity with carrier concentrations of 10^{18}-10^{19} cm^{-3} and mobilities of 84-110 $cm^2/V.s$. Though the electrical data presented are not too impressive, the further development and progress of the technique should be carefully followed.

- Molecular Beam Epitaxy

In the late news session, another method of controlling a monolayer thickness of GaAs layers was discussed in the paper on "Computer Controlled Phase-locked Epitaxy (PLE) of $(GaAs)_n$ $(AlAs)_n$ using RHEED Oscillations," by T. Sakamoto *et al.*, of the Electrotechnical Laboratory. They have observed strong intensity oscillations over more than 400 periods in the reflection high energy electron diffraction (RHEED) from GaAs and $Al_xGa_{1-x}As$ during MBE growth. A period of the RHEED oscillations corresponded to one monolayer thickness (2.83 Å in GaAs). By analyzing the phase of the RHEED oscillations by a computer and with the molecular beam shutters operated at a particular phase, superlattice structures with an integral number of monolayers were realized. Using these oscillations, the impinging rates of Ga and Al and even the Al mole fraction x of $Al_x Ga_{1-x} As$ can be accurately determined.

The PLE process is termed the ultimate technology in the field of semiconductor electronics and some researchers have described the technology as the "genetic recombination" of the field of electronics. The achievement can certainly be regarded as an important step toward a superlattice semiconductor.

Other advances in the MBE growth of GaAs were made by the Astugi Electrical Communication Laboratory of Nippon Telegraph and Telephone Public Corporation (NTT). M. Shinohara *et al.*, described the defect-free growth procedures of GaAs in their paper on the electrical properties of surface defects on molecular beam epitaxially grown GaAs layers and defect-free growth procedures. Though high quality MBE-grown GaAs layers are now available for fabrication of optical and electronic devices as a result of progress in growth technologies, the use of MBE-grown layers for IC fabrications has been hindered because of a high density of surface defects called "oval defects," $\sim 10^3/cm^2$, produced during the growth. From a study of the mechanism of oval defect formation, NTT workers concluded that Ga droplets resulting from the dissociation of Ga oxides on the Ga melt source were responsible for oval defect formation in a usual growth rate range (0.4-3 μm/hr).

They obtained nearly defect-free GaAs layers (the defect density of less than $500/cm^2$) at a practical growth rate of 1 μm/hr by establishing procedures for Ga source oxidation. Procedures adopted include:

- long-time chamber backing (>72 hours),
- Ga cell preheating to about 1200°C under shutter-opened conditions after charging the Ga source,
- charging the Ga source in a dry N_2 atmosphere.

- Semiconductor Lasers--Visible

In Japan, there are strong R&D efforts in developing visible laser diodes below 0.7 μm wavelength for high density optical information processing and optical communica-

tion. Candidate materials considered for investigation are AlInGaP (0.58-0.70 μm), InGaAsP (0.65-0.87 μm) and AlGaAs (0.68-0.9 μm). For fabrication of LDs, conventional LPE technology is rapidly being replaced by CVD and MOCVD.

In the late news session, Kobayashi *et al.*, of NEC Corporation, reported the room temperature pulsed operation of an AlGaInP DH laser at 626.2 μm wavelength by low pressure (70 Torr) MOCVD at the substrate temperature of 800°C. The laser structure has a current confinement stripe width of 20 μm. Threshold current density of about 50 kA/cm² was obtained.

A cw operation of a AlGaInP DH laser diode at 77 K grown by atmospheric MOCVD was discussed by M. Ikeda *et al.*, of the Sony Corporation Research Center. The diode lasing at 653 μm in a cw mode at 77 K had a threshold current density of 2.4 kA/cm². The DH diode was also operated in a pulsed mode at room temperature with the pulsed threshold current density of 15 kA/cm².

A visible laser diode at 0.65 μm using a InGaAsP/GaAsP system was reported by I. Mito *et al.*, of NEC Corporation. A DH laser structure was grown by hydride transport vapor phase epitaxy (HT-VPE). Under a pulsed condition, the threshold current density of as low as 5.6 kA/cm² was obtained. This is the lowest threshold current density reported for the diode operating at 0.65 μm. A cw operation up to -27°C was also possible with this diode. (A Soviet participant claimed that they have a diode operating at 1.5 kA/cm² fabricated from a LPE grown structure.)

- Superlattice and Heterostructures

Two-dimensional electron gas confined in a new type of heterostructure--the selectively doped InP/n-AlInAs is observed, for the first time, by M. Inoue of the Osaka Institute of Technology and S. Nakajima of Osaka University. The new heterostructure consists of n-type $Al_{0.48}In_{0.52}As$ and semi-insulating InP substrates. It was prepared by conventional LPE growth of 0.3μ thick AlInAs lattice matched to InP. The electron density of 2DEG is controlled by Si donors in AlInAs. The conduction band discontinuity is estimated to be about 0.2 eV. The evidence of the two-dimensional character of electrons confined in the InP layer was provided by observations of quantum oscillations of magneto resistance and quantum Hall steps. Much larger amplitudes of quantum oscillations and higher mobilities were observed in this system compared with the selectively doped GaAs/n-AlGaAs heterostructure grown by the LPE technique. The authors believe that this system has enormous potential as a fundamental structure for high frequency devices relative to GaAs devices.

J. Komeno *et al.*, of Fujitsu, described $In_{0.53}Ga_{0.47}As$/InP superlattices in the invited talk. The superlattices were grown by the chloride transport vapor phase epitaxy (chloride VPE) technique. Evidence of two-dimensional electron gas was previously demonstrated in the selectively doped InGaAs/InAlAs and InGaAs/InP heterostructures grown by MBE and low pressure MOCVD, respectively. However, this is the first successful growth of InGaAs/InP superlattices with the chloride VPE method which uses the $AsCl_3$-Ga-In-H_2 and the PCl_3-In-H_2 systems. There are several important reasons for employing the chloride VPE method instead of MOCVD or MBE. Since this method does not use AsH_3, PH_3, and organic metal compounds, the technique is considered safer than MOCVD. In comparison to MBE, it offers a lower cost and a higher production yield. High purity InP and InGaAs are being grown using the chloride VPE process.

The thickness of the heterointerface, as determined by Auger electron spectroscopy, was found to be less than 30Å. To obtain an abrupt heterointerface, it was necessary to reduce the growth rates of both InGaAs (∿3Å/s) and InP (12Å/s) by controlling partial pressure of HCL.

InGaAs/InP multiple quantum well (MQW) structures, having different well widths, have been prepared for photoluminescence and absorption measurements. Optically pumped MQW structures exhibited the lasing transition at 1.550 μm for 1.2 times the threshold power Po. Po is found to be about 740 W/cm². A characteristic temperature To value of as high as 137 K was obtained from the temperature dependence of the threshold excitation power. The To value of 137 K is much higher than that of the double heterostructure (DH) structure. This is the first observation of improvement in the To value in the 1.3-1.6μm lasers. However, no data were presented on the electrically pumped lasers. Fabrication of the quantum well heterostructure (QWH) lasers by the chloride VPE method can be construed as a remarkable achievement.

- Focused Ion Beam Technology

Progress on maskless ion implantation using a submicrometer focused ion beam (FIB) was discussed by H. Hashimoto and E. Miyauchi of the Optoelectronics Joint Research Laboratory (OJRL) at the session on OEIC (optoelectronic integrated circuits).

Focused ion beam technology has recently generated increased attention in Japanese laboratories as a potential tool for maskless microfabrication of semiconductor devices. A large number of articles dealing with submicron ion beam technology are visible in the scientific and technical journals, and a great deal of activity in maskless ion implantation, etching, and scanning lithography has been observed.

H. Hashimoto gave an overview on the various activities involving FIB at OJRL. He described a novel system which combined the MBE and FIB that was constructed at OJRL. Research activities at OJRL are primarily directed toward the realization of planar-type OEIC. The 100 keV OJRL/FIB system is equipped with an Au-Si-Be liquid meal (LM) ion source and an EXB mass separator. The implanter can focus ion beams down to less than 0.1 μm in diameter. Through the sample transfer chamber of ultrahigh vacuum (∿$5x10^{-10}$ Torr), the implanter was connected to the MBE system.

With this combined system, they were able to form p (Be)- and/or n (Si)-type fine patterns on MBE-grown GaAs layers with little damage. Preliminary results indicated that the system is capable of producing good quality selectively doped layers. Progress is impressive and the system is expected to have a great impact on future OEIC fabrication processes.

In the session on process technology (II) (lithography and materials), T. Kanayama *et al.*, of the Electrotechnical Laboratory reported on the work of the fine pattern definition with focused ion beams and its application to x-ray mask fabrication. In their paper, they proposed a new pattern definition method using atomic intermixing induced by FIB. The sample, consisting of double layers of 18 nm Al and 203 nm Au, was first irradiated with a 0.2μm diameter 50 keV Ga FIB. As a result of irradiation, the intermixed Al-Au region, which provides a higher sputtering rate than the top Al layer, is formed. By ion milling the layers with 4 keV Xe ions in an O_2 ambient of $5x10^{-3}$ Pa, grooves with a width less than a quarter micron are successfully formed.

With the use of this method, x-ray masks were fabricated. From the fabricated mask, steep patterns narrower than 0.2 μm were transferred to PMMA coated on Si substrated with synchrotron radiation.

- MOCVD

In the sessions on MOCVD and late news, several advances in the growth of III-V, II-VI materials, and III-V device structures by MOCVD were reported. With the MOCVD technique, it is now possible to grow high purity materials of GaAs, InP, and InGaAs.

In the paper on the high purity InP growth by low-pressure metal-organic chemical vapor deposition, K. Uwai *et al.*, of the Musashino Electrical Communiations Laboratory (ECL), NTT, reported high purity InP epitaxial layers with electron mobilities higher than 70,000 $cm^2/V.s$ at 77 K and Nd-Na lower than $1x10^{15}$ cm^{-3}. Optimum growth conditions for the high purity layers are found to be at growth temperatures between 550°C and 575°C and $[PH_3]/[TEI]$ of 170.

N. Kobayashi and T. Fukui of the Musashino ECL, NTT, described selectively doped (SD) GaAs/n-$Al_{0.3}Ga_{0.7}As$ heterostructures grown by low pressure (80 Torr) MOCVD. A 2DEG mobility of 150,000 $cm^2/V.s$ was obtained for a sheet electron concentration (Ns) of $6.9x10^{11}$ cm^{-2} at 4.2 K. This value is much lower than the 2DEG mobility of 2,120,000 $cm^2/V.s$ at 5 K of the SD GaAs/n-AlGaAs grown by MBE. However, the very abrupt heterointerface of less than 6Å, as determined by Auger electron spectroscopy, was achieved. The authors believe that the 2DEG mobility can be further increased if TEG and TEA are used in place of TMG and TMA.

Low pressure (LP) MOCVD growth and characterization of AlGaInP materials using a self-cracking system (SCS) for the group V hydride PH_3 was reported by Y. Ban *et al.*, of Matsushita Electric Industrial Company. Because of the difficulty of controlling the Al composition due to a large segregation coefficient under thermally equilibrium conditions, it is not easy to grow AlGaInP by LPE. Therefore, AlGaInP systems are successfully grown by MOCVD or MBE. In order to increase the incorporation efficiency of P and In atoms and to avoid the formation of nonvolatile compounds, PH_3, has to be precracked in low pressure MOCVD. Instead of using an additional furnace to precrack PH_3, they devised a self-cracking system (SCS) which is located near the rf-heated susceptor in the form of a U-shaped line. They found that the incorporation efficiency of In atoms in InGaP is higher for LP-SCS than that for the conventional LP system, and the efficiency of AlInP did not depend on growth temperatures or growth methods. Alloy compositions x, y, in $(AlxGa_{1-x})y\ In_{1-y}P$ were independent of PH_3 flow rates and growth temperatures in the range between 650 and 775°C. AlGaInP layers had the carrier concentration of $5x10^{10}$ cm^{-3} and the Hall mobility of 700 $cm^2/V.s$.

CONCLUDING REMARKS

The conference was truly a Japanese show, though there was an international flavor. Since a total of 218 papers, including the late news and last minute papers, were packed into a three-day meeting and spread over four-parallel sessions, many noteworthy papers were missed as it was a difficult decision to select those papers that did not conflict with other interesting presentations. Nevertheless, the program was well-planned considering the magnitude and scope of the meeting. It served as an excellent vehicle in which to observe and obtain an overview of current Japanese activities in semiconductor devices and materials. Discussions at the meeting were lively and extensive. Many "firsts" in

accomplishments were claimed. Some of the papers presented at the meeting had received extensive publicity via the news media prior to the meeting. It seems to be the customary practice of many Japanese industries to announce their achievements to the news media just before an international conference.

Nonetheless, unusual enthusiasm and pride was detected in the presentations. There were many other excellent papers from foreign countries which were not discussed here since this article is intended to cover Japanese progress. Examples of outstanding papers from the United States are:

- "Monolithic integration of GaAs and Si," by J. C. C. Fan, Lincoln Laboratory, Massachusetts Institute of Technology (MIT),
- "Recent advances in GaAs/(Ga,Al) As heterojunction bipolar transistors," by P. M. Asbeck and D. L. Miller, Rockwell International, Microelectronics Research and Development Center.

More active participation by U. S. scientists in future meetings is recommended.

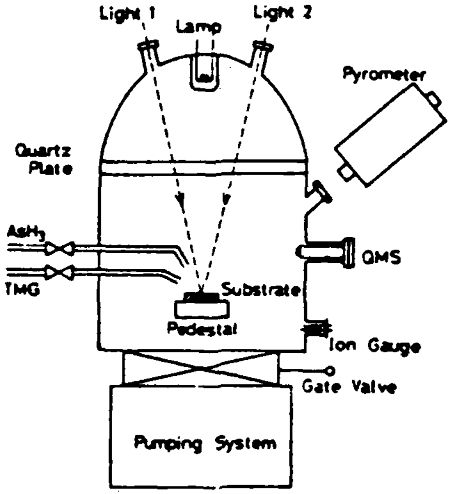


図1：成長装置の概略図

Figure 1. Photomolecular epitaxy system.
Source: Taken from the report (SSD 84-55) from the technical meeting of the technical group on semiconductors and semiconductor devices of the Institute of Electronics and Communication Engineers of Japan, 27 August 1984.

AN AUSTRALIAN APPROACH TO DEVELOPMENT OF MANUFACTURING TECHNOLOGY

Thomas W. Eagar

INTRODUCTION

Australia has abundant natural resources and a strong agricultural base; however, with only 1.5% of the developed world's population, it is necessary for Australia to import most of its technology. A recent study has shown that there is a seven to nine year lapse between the first worldwide demonstration of a technology and its implementation in Australia. This lag is approximately equally divided between the time required for recognition of the technology and the time required to develop Australian expertise in the technology. With the accelerated pace of worldwide development, Australians must work to shorten this time if they are to maintain a viable, local manufacturing industry. To help achieve this, a long-range national goal is to increase the number of students completing secondary education from 40% to 60% and to increase the number of persons with some tertiary education from 8% to 20%. In the short-term, the governmental Commonwealth Scientific and Industrial Research Organization (CSIRO) has established the Division of Manufacturing Technology to aid local industry in research and development.

Overall, CSIRO has 7000 employees in the agricultural, physical, and engineering sciences and represents Australia's major nondefense governmental research and development effort. The work of several CSIRO divisions, including some of the work within the Division of Manufacturing Technology, has been reviewed by Dr. M. Koczak [*see Scientific Bulletin, 8*, (1) 1 (1983)]. The present report describes the general philosophy and recent successes of the Manufacturing Technology Division in somewhat more detail.

Dr. W. J. McG. Tegart, Secretary of the Department of Science and Technology, of which CSIRO is a part, explains that in the past Australia has emphasized basic research, but now there is a great need to emphasize the application of science to Australian industry and agriculture. The Division of Manufacturing Technology (DMT) was established to help fulfill part of this need. Some of the agricultural divisions at CSIRO are also emphasizing the application of existing science rather than the exploration of new science.

ORGANIZATION OF THE DIVISION

In April 1980, 65 staff members of the Division of Materials Science were transferred to the new Division of Manufacturing Technology located in Adelaide and Melbourne. Since that time, the total staff has grown to 110 which is remarkable compared with the small or nonexistent growth of other divisions of CSIRO over the same period. The research budget is A$4.0 million of which 90% comes from the government and 10% comes from collaborative work with industrial firms.

The division is comprised of eight main areas as shown in the appendix. The groupings appear somewhat arbitrary, and are based primarily on the previous expertise of the staff which were originally transferred from the Division of Materials Science. The individual staff members are extremely capable, with many, if not most of the professional personnel holding doctorates in science and engineering. The facilities, although not outstanding, are reasonable and the staff seems to make excellent use of what is available. There is a strong analytical component to their research in spite of the admittedly applied goals which they have established. The division represents a unique resource for Australian

industry. Because of its generally small size and limited market, Australian industry could not maintain a staff of such high quality and technical expertise.

A major premise of the division is that technology applications are driven primarily by "market pull" rather than "science push." Accordingly, members of the division are constantly striving to understand the problems experienced by Australian industry and are looking for existing technologies which can be applied to the solution of these problems.

The preferred method of industrial interaction for the division is the establishment of a collaborative research agreement. The division seeks specific requests from individual companies or groups of companies. Each request from industry is evaluated by the division and selections are made based upon the resources available in the division. As noted above, some of the costs of the collaboration are paid for by the company, usually through the provision of materials, equipment, and company staff members which are assigned to work alongside the division staff members. It is apparent from the division budget sources that the bulk of the work is paid for by the government. In effect, the division is providing a subsidy to the Australian manufacturing industry in the hope of making them more efficient at home and more competitive in the international market. In return, the collaborative agreement establishes patent royalty rights for the government should the research prove to be commercially successful. As a result, over the past four years the staff of the division have substantially reduced the extent of the publication of their research efforts and have emphasized patent protection of their developments.

Other forms of industrial assistance include ad hoc consultation and development or marketing advice for new products or processes.

INITIAL SUCCESSES OF THE DIVISION

In the Integrated Engineering Manufacturing section of the Melbourne Laboratory (see the appendix), Dr. W. Gellie and his staff members have been studying real time vision sensing. They began their work with one of the first commercial vision systems produced by Automatix, Inc. of Burlington, Massachusetts. The Automatix system processes the information off-line. By developing their own software and a VLSI preprocessor of their own design, Dr. Gellie's group has created a vision system which can operate in real time. Their algorithm does not process the image point by point and as a result can produce the Stanford Research Institute (SRI) parameters of a 256x256 pixel screen in one millisecond. They believe that their system leads worldwide technology by 12 months and they are actively working with a firm which will market it. The estimated cost is $10-15 thousand which is considerably cheaper than existing vision systems.

In the Die Casting section, Dr. R. Esdaile, along with his staff members, have been studying convection during die filling. This work has led to a computer program for die design and manufacture which is to be marketed internationally by Mould Flow, Ltd. In addition, work within this group is credited with solving a cracking problem which preserved a major international market for an Australian die casting firm. Future work is planned to develop new die materials, especially using ceramic inserts.

Dr. G. Ogilvie of the Arc Technics section of the Melbourne Laboratory, has developed a pulsed-current welding power supply with closed loop control. This unit appears to be a significant advance over the open loop control Synergic system developed by the British Welding Institute several years ago. The unit is currently produced by Welding Industries of Australia Pty, Ltd., P. O. Box 49, Thomastown, Victoria, and has been a substantial success in Australia. Worldwide marketing is planned. It is reported that this

unit permits all position welding with flux-cored electrodes that otherwise are not acceptable in out-of-position welding situations.

Dr. I. French, of the Welding section, in the Adelaide laboratory, has developed a flux-cored welding electrode technology for Australian industry. Although this technology is not unique internationally, it has not been available through domestic suppliers which has put the industry at a disadvantage with importers in the local market place. Future work is planned for a flux-cored electrode for use with HY80 in a Australian initiative to build six of their own submarines.

SUMMARY

The Division of Manufacturing Technology is an interesting Australian experiment in which a government laboratory is trying to improve the country's manufacturing technology base. The division provides a uniquely capable professional staff who are eager to apply their knowledge to practical industrial problems. The division provides Australian industrial firms, which are generally small and unable to maintain a large engineering staff, with exceptional research ability at a nominal cost. In the four years that it has been established, the division can point to a number of commercial successes. If they can maintain the pace of these accomplishments, the Division of Manufacturing Technology will not only have achieved its original goal but it will become a significant resource for Australian industry as they try to maintain their competitiveness in worldwide manufacturing technology.

Further inquiries about the Division of Manufacturing Technology may be directed to:

Dr. R. H. Brown
Chief, Division of Manufacturing Technology
175 Johnston Street
Fitzroy, Victoria 3065
Australia

APPENDIX

CSIRO
DIVISION OF MANUFACTURING TECHNOLOGY

MELBOURNE LABORATORY

Arc Technics	- development of pulse welding equipment - physical studies of melting electrode using pulsed currents - high current dc switching - seam tracking sensors for automatic welding
Die Casting	- analysis of fluid and thermal flow - computer-aided design of dies - thermal control of dies - improved process control and improved strength of components - development of new zinc alloys - application of advanced materials in die casting equipment
Machining and Tribology	- performance of new types of cutting tools - machinability of materials - nature of tool failure during interrupted cutting - friction and wear of ceramic materials - polishing of hard materials
Integrated Engineering	- development and application of flexible manufacturing systems - application and interaction of robots with other manufacturing devices - development of VLSI circuits for vision interpretation and control purposes - computer-aided design

ADELAIDE LABORATORY

Welding	- methods of producing hard-faced materials - manufacturing methods for welding consumables - plasma arc spray - narrow gap welding systems
Metal Forming	- material behavior in forming - computer strain analysis in sheet forming - shape conformity in shallow automobile panels - press and tool instrumentation - tool wear, draw bead and galling in sheet forming
Materials	- casting methods for ferrous materials--quality and productivity - alloy design for wear resistance - properties of wear-resistant castings

Product Design	- various design for production studies, current activities: - manufacture of tubular products - computer-aided design and draughting applications	

INTERNATIONAL CONFERENCE ON HIGH STRENGTH LOW ALLOY STEELS

Thomas W. Eagar

OVERVIEW

This year's international conference on high-strength low-alloy steels was held at the University of Wollongong, New South Wales, Australia, from 20-24 August. Nearly 150 delegates from 14 countries gathered to hear 55 papers. Nine keynote presentations were made with two each from Australia, Japan, the United Kingdom, the United States, and one from Canada.

The growing importance of HSLA steels is demonstrated by the fact that these steels now include 5% of the world's steel tonnage. The United States leads in use with 5M tons per year followed closely by Japan at 4M tons per year. Tata Iron and Steel of India reports that the average strength of their product has increased from 254 MPa to 320 MPa over the past ten years.

At this year's conference, there were a number of changes from previous years. The use of controlled rolling and low finishing temperatures was deemphasized. Instead, most of the reports were on recrystallization controlled rolling (RCR) in which high finishing temperatures, often coupled with accelerated cooling, are used to achieve fine grain size yielding high strength with good toughness. The use of higher finishing temperatures requires titanium either alone or in combination with Nb and V. The high stability of TiN, with the fine distribution achievable in continuously cast steels, helps prevent excessive austenite grain growth at high working temperatures. These high working temperatures not only eliminate the separations on the impact fracture surface of Nb-V controlled rolled steels, but they permit higher production rates by eliminating the time spent cooling the plate on the mill. In addition, they allow production on the smaller, often older mills which are prevalent in less developed countries. It is clear that the successful development of these RCR Ti-bearing steels will increase the number of worldwide producers of HSLA steels and should lead to significant increases in their use.

Although most of the papers emphasized the processing of the steels rather than their properties, a common complaint, especially from users of the steels, was that the weldability of the steels has not increased significantly over the past ten years. While this may be true on a worldwide scale, it is not true of Japan where steels of ultralow carbon equivalent have been developed in recent years through the use of new processing techniques such as accelerated cooling. One owner of offshore platforms noted that the steel represented only 3% of the cost of the structure while fabrication was 15% of the total cost. There was considerable debate over whether the traditional weldability parameters, such as carbon equivalent, were of any real use with these HSLA steels.

A number of countries or companies were conspicuous by their absence. Korea, Taiwan, and the Soviet Union did not send representatives. No representatives were present from steel suppliers in North America or Europe--most likely due to the depressed state of their businesses. As might be expected, the People's Republic of China, India, and Australia were well-represented, but only four of the five largest Japanese firms sent representatives and in those cases only one or two persons came. This is due in part to the fact that all Japanese steel companies, for the past year or two, have been emphasizing research on alternate materials such as titanium and high strength aluminum alloys.

Overall, there were no striking new developments presented at this conference. The knowledge and use of these steels will continue to progress with gradual changes in emphasis and need. The decreased research in the United States, Japan, and Europe due to the depressed world steel economy suggests that improvements may not be developed as rapidly in the future, but the intense interest by some of the less developed countries suggests that the use of HSLA steels will continue to grow.

CONFERENCE HIGHLIGHTS

In the opening technical address to the conference, Dr. M. Korchynsky of Union Carbide Metals in Pittsburgh noted that HSLA steels can save 25 to 50% of the weight of conventional steels. He predicted a continued increase in their use if only because they permit greater effective utilization of steel capacity, particularly in less developed nations. He pointed out that countries such as China, which produces 35 kg of steel per person per year, have a great need for more steel when compared with Japan or the United States which uses 700 kg per person.

Dr. C. Ouchi of Nippon Kokan in Japan, reviewed the development of accelerated cooling since NKK's first plate mill installation of this process in 1979. He emphasized the need to begin cooling at 750°C for microalloyed steels and to halt cooling at 625°C. Very low nitrogen is required to prevent formation of bainite, and hence a reduction in plate toughness.

In terms of improving weldability, Dr. T. Tanaka of Kawasaki Steel noted that the 25% reduction of carbon equivalent in accelerated cooled steels permits a 100°C reduction in weld preheat requirements, while Dr. S. Yano of Nippon Steel emphasized the need for very low nitrogen, coupled with small Ti and B additions for the best weld HAZ toughness in accelerated cooled plates.

Professor J. Jonas of McGill University, Montreal, Canada, presented several studies on dynamic recrystallization as measured by high rate compression loading. Through this work they are able to rank Nb, Ti, Cu, Al, Mo, V, Ni, Mn, Cr, and Si in decreasing order as retarding recrystallization at a 0.1 wt.% level in steel.

In an interesting fundamental study of nucleation behavior in HSLA steels, Professor I. Tamura of Kyoto University, showed that the prior austenite grain boundaries are the dominant site for ferrite nucleation; however, at accumulated strains of greater than 30%, ferrite also nucleates at annealing twin boundaries. Making several assumptions, he was able to show that the grain boundary nucleation rate at 30% strain was 740 times greater than the unstrained nucleation rate, while at 50% strain the rate increased by a factor of 4200. He also showed that some disk-shaped ferrite grains nucleate within the austenite grains on (101) austenite planes.

Professor C. M. Sellars of the University of Sheffield, United Kingdom, presented a mathematical model capable of predicting the recrystallized austenite and ferrite grain sizes as a function of the hot rolling sequence. He and other authors showed that light rolling passes of less than 10% can coarsen the grain size rather than refine it.

Professor M. N. Shetty of the Indian Institute of Technology in Kanpur, India, noted that there is little interaction between university and industrial research in India. He also described the success of their undergraduate program in metallurgy by noting that nearly 50% of their graduates continue studies in the United States.

Dr. Bufalini of Centro Sperimentale Metallurgico (CSM) in Italy noted their experience with accelerated cooled steels. He also demonstrated that acicular ferrite is much more resistant to stress corrosion cracking in hydrogen sulfide sour gas environments. Sulfide morphology does not seem to have an effect, but they found that the cracks originate in the pearlite colonies.

Dr. Brian Jones of the Niobium Products Company in Pittsburgh noted the trend toward higher finishing temperatures to avoid separations on the Charpy fracture surfaces. He also stated that a new Brown and Root Corporation specification prohibits rolling of plate below 750°C, presumably to prevent separations.

Dr. F. Nakasoto of the Sumitomo Steel Corporation reported on the somewhat unusual development of a high toughness concrete-reinforcing bar for use at liquid nitrogen temperatures. Possible applications include concrete structures in the arctic and liquid natural gas storage tanks. Dr. C. Killmore of Australian Iron and Steel Pty., (a wholly-owned subsidiary of Broken Hill Proprietary), described the development of a surface quenched and tempered reinforcing bar. The bar is water-cooled off the mill, but the amount of water is limited such that the core of the bar remains hot. On further air cooling, the water quenched surface is tempered by the heat diffusing out of the core. This results in a tempered martensitic sheath with a fine ferrite core in the bar. The low carbon equivalent of 0.32 permits ease of welding and one times thickness bending.

Dr. E. Navara of the Lulea University of Technology in Sweden described an annealing treatment at 725°C for plain carbon steels which will produce a dual phase microstructure in plate of virtually any thickness. Essentially, this anneal for extended times just above the eutectoid temperature in the two-phase region causes partitioning of Mn with greater concentrations in the austenite phase. He showed that 60% increases in Mn concentration in the austenite were possible with eight hours annealing. Although this represents an interesting application of the physical solubility differences in a two-phase region, its practical application is questionable due to the very tight temperature control and long annealing times which are required.

Finally, Mr. R. T. Mostert of ISCOR Research and Development, Pretoria, South Africa, presented a confirmation of the phenomena of superhardenability. Superhardenability was first described in an article by GKN Industries of Great Britain nearly two years ago. They found that steel which had high aluminum (greater than 0.1%) and was cast with a high superheat temperature (e.g., 1650°C) had much greater hardenability than predicted from the Grossman hardenability formula. ISCOR has shown that the increase can be as much as a factor of three; and they project cost advantages of up to $200 per ton for superhardenable steel plates as compared with conventionally processed steel. Significant improvements in weldability should also be possible with appropriate modification of the plate composition. Unfortunately, no one seems to know what causes this increase in hardenability. Some people believe that it is only the result of residual boron which is rendered a much more potent hardening addition due to the interaction of the aluminum with the nitrogen in the steel. During questioning one attendee stated that as little as one-half ppm boron can influence hardenability when such high aluminum is added to the steel.

CONCLUDING REMARKS

Interest in the use of HSLA steels is increasing, especially in less developed countries. This is at least partly due to the development of new steels which can be processed on conventional equipment and it is partly due to a need by less developed

countries to make more effective use of their production capacity. In light of a depressed world steel economy, and the underutilization of capacity in the more highly developed countries, these facts appear to be contradictory. In fact, these factors suggest that exports of steel from the more developed nations to the less developed nations will continue to decrease thus leading to even greater problems for steel-exporting nations, but perhaps improved trade balances for the less developed countries.

WELDING TECHNOLOGY AND HIGH STRENGTH STEELS FOR MARINE STRUCTURES: VISITS TO JAPANESE SHIPYARDS

Harry I. McHenry

Japan is the leading shipbuilding nation in the world with a market share of about 45%. During the shipbuilding boom from the mid-1960s to the mid-1970s, Japan produced about 50% of the total world tonnage. Shipbuilding capacity peaked in 1974 about the same time as the first oil shock. Six new yards were completed in the early 1970s, each designed for the construction of about six supertankers per year. The market for these large ships quickly disappeared, but the excess capacity was effectively used to supply offshore structures for the ensuing oil exploration boom. This boom ended in the early 1980s leaving the shipyards to scramble for new business wherever it could be found. To avoid catastrophic price competition, the industry cooperated with a government-organized rationalization to reduce capacity by closing selected facilities at each shipyard. At the time of my visits (1983, 1984), a large number of bulk carriers in the 40,000 DWT-size range were being built as part of a speculative scheme to take advantage of rock bottom prices. In addition, selected parts of the oil exploration business remained active. In particular, arctic projects resulted in several orders and led to a high level of development work related to steel structures for low temperature service.

This report was prepared to review welding technology in Japanese shipyards and the usage of high strength steels in ships and offshore structures. Current practice is summarized and trends in the technology are discussed. The report is based on visits to the following shipyards:

COMPANY	FACILITY
Hakodate Dock	Muroran Works
Hitachi Zosen	Ariake Works Sakai Works Sakai Research Center
Ishikawajima-Harima Heavy Industries, (IHI)	Yokohama Research Institute
Kawasaki Heavy Industries	Sakaide Works
Mitsubishi Heavy Industry	Koyagi Works Nagasaki Technical Center Takasago Technical Center
Mitsui Shipbuilding and Engineering	Chiba Works Tamano Works
Nippon Kokan (NKK)	Tsu Works Tsurumi Works Tsu Research Laboratories
Sumitomo Heavy Industries	Oppama Works Uraga Works

WELDING TECHNOLOGY

The welding practices used for ship construction in Japan may be categorized as follows:

	CURRENT USAGE	TREND
manual welding	10-20%	decreasing
gravity welding	15-20%	constant
semiautomatic welding	40-55%	increasing
automatic welding	15-20%	constant

Manual welding done by the shielded metal arc welding (SMAW) process is being gradually replaced by semiautomatic welding by gas metal arc welding (GMAW) and flux core arc welding (FCAW). FCAW with CO_2 gas coverage and seamless cored wire has become particularly popular. Automatic welding includes submerged arc welding (SAW), electrogas welding (EGW), and electroslag welding (ESW). The EGW process using a small diameter wire and a double-V joint preparation has replaced ESW and SMAW for vertical welding during erection.

The trend in SMAW is down, but this versatile process remains an important tool for ship construction. During preassembly and assembly stages, SMAW is limited to tack welding and a few isolated applications. It seems to be a matter of pride to rid the shops of electrodes. However, during the erection stage, as much as 50% of the welding may be done by the SMAW process.

The SMAW process is also used in conjunction with automatic welding. For example, at the Ariake Works when the deck longitudinals are welded by the consumable guide electroslag process, the deck plate is welded by putting in one or two passes by the SMAW process and subsequently filling the joint by SAW.

For jack up rigs, HT80 steel (tensile strength is 112 ksi) is commonly used for the main columns, the racks, and some bracing. Here, SMAW electrodes with extralow hydrogen are used for rack-to-rack welds and sometimes for chord-to-chord or chord-to-rack welds. For further protection against hydrogen cracking, the first two passes in butt joints may be put in by the gas tungsten arc (GTA) process.

Recent developments in the area of electrodes for SMAW include electrodes with 20-50% lower fume volume, electrodes with superlow hydrogen (2-3 cc/100 g) and ultralow hydrogen (0.7-1.2 cc/100 g) for welding HT50 through HT80 grades, and electrodes for arctic service with good impact properties to -60°C.

- Gravity Welding

The use of gravity welding for fillet welding in the flat position remains the most common method of welding vertical stiffeners to flat plates. It continues to account for about 15% of the total welding as it has for about 20 years. Attempts to replace gravity welding with automated CO_2 welding have not been successful. Gravity welding is simply too efficient with a single welder being able to handle up to six units simultaneously during preassembly and up to 10 units during the assembly stage.

A variation on gravity welding, which is useful in more confined spaces, is low-angle spring-type welding. The same electrodes can be used and one worker can handle several jigs (three-six sets). The Kobe Steel version is called "Auto-Contact Welding." Nippon Steel has recently introduced a variation of this process called RELAYAUTO. In this process, a series of machines is setup along the desired weld length. The arc is automatically relayed from one machine to the next by a welding current detector. Thus, a further increase in welder efficiency is possible, particularly for longer lengths of fillet welds.

The gravity welding process is widely used for horizontal fillet welding, but variations have been developed for butt welding. Nippon Steel has introduced a new model at the International Welding Exhibition in Osaka (October 1983) called TWINAUTO which is suitable for erection welding where there are large fluctuations in root gap. A special electrode consisting of two side-by-side cored wires of 6 mm diameter is used. The electrode is turned such that its effective width corresponds to the root gap. Gaps from 4 to 12 mm can be welded.

- Semiautomatic Welding

The semiautomatic welding processes include numerous variations of the gas metal arc welding (GMAW) process, including MIG, CO_2, FCAW, pulsed-arc, and mixed gas (MAG). Shipyards have been relatively slow and cautious in the adaption of the semiautomatic processes. However, over the past five years, there has been a remarkable increase in semiautomatic welding, particularly in the use of CO_2 shielded FCAW. For example, at the Ariake Works of Hitachi Zosen, the use of CO_2 semiautomatic welding has increased from about 3% to 45% of total welding over the past four years. This process has high deposition rates, deep weld penetration, good quality and appearance characteristics, and all position capability. The versatility of the process has been increased by the development of long-reach wire feeding systems, backing strips for one-side welding, and lightweight carriage devices (e.g., Nippon Steel's Carry Boy or Kobe Steel's Picomax) for automatic torch movement.

The main innovation in the CO_2 FCAW process has been the development of a seamless flux-cored wire. This was first developed by Oerlicon in Europe, but has been licensed in Japan by Kobe Steel (DEXCEL wire) and Nippon Steel (SF wire). Normally, flux-cored wire is made by wrapping steel strips around a flux and then drawing it into a wire that has a seam. In the new process, seamless tubes are filled with flux and then drawn into wire. The welding characteristics of the two types of wire are quite similar. However, elimination of the seam permits the use of copper coating rather than oil; reduces moisture pickup, thereby lowering the hydrogen content (typical value is 0.7 cc/100 g) of the weld metal; and lowers the welding fume to about the level of solid wire. Copper coating improves the corrosion resistance slightly, but more importantly, it significantly improves the wire feeding characteristics. Oil coating tends to gum up wire feed mechanisms, so periodic (about once daily) cleaning is necessary. The main disadvantage of seamless wire is cost, which is 10 to 20% higher than seamed wire.

Other semiautomatic processes used in shipyards are MAG (argon plus 20% CO_2) welding with solid wire, self-shielded (no gas required) FCAW, and pulsed-arc GMAW. MAG welding is commonly used for numerous applications. Self-shielded FCAW welding is not too popular for shipbuilding, but it is sometimes used for offshore structures where wind protection is a problem. Pulsed-arc GMAW is sometimes used and further applications are under evaluation, e.g., low temperature applications and overhead welding.

- Automatic Welding

SAW continues to be the principal method of making butt welds in the flat position during the assembly stage, accounting for 15% of total welding. The equipment for SAW is mostly of the one-side-welding variety and the procedures have changed little over the past ten years. Flux copper backing (FCB) remains the most common method for butt welding seams on a panel line. Gantry-mounted double and triple tandem arc SAW systems are used for the FCB welds. The flux asbestos backing (FAB) method, which features a flexible backing strip is commonly used for curved sections and straight lengths in the later stages of assembly and in erection. Tractor-type, single or double arc units are used for the FAB welds and both-side welds.

A modification to the multiple electrode submerged arc welding process has been developed that effectively lowers the heat input while maintaining a high deposition rate. This has been accomplished by separating the lead and trailing electrodes by distances up to 1 meter. The idea is that the lead electrode deposits a weld that solidifies and cools below the transformation temperature before the trailing electrodes add to this deposit. The problem that had to be overcome was arc stability in the trailing electrodes. Different approaches have been used by different companies. In the case of Nippon Steel, stability is provided by spacing the two trailing electrodes sufficiently close (10 mm or less) so that an arc was maintained between the electrodes. With this process, it is possible to weld thicknesses up to 32 mm in one or two passes and meet Charpy throughness requirements at temperatures as low as -60°C.

For vertical welding, the electrogas welding process has been modified to permit use of lower heat inputs. This process is being used by nearly all of the shipyards visited for vertical butt welds during the erection stage. The modified process is called vibratory electrogas welding (VEGA) by Nippon Steel and SEGARC by Kobe Steel. A schematic diagram of the SEGARC welding process and typical welding parameters are shown in Figure 1. The key modifications are: use of small diameter flux-cored wire and CO_2 shielding gas, through-the-thickness oscillation of the torch, and the use of a beveled groove. Weld shape is controlled by a fixed copper shoe at the weld root and a sliding, water-cooled copper shoe at the face.

The ESW process was commonly used to make the side-shell butts during erection of supertankers. Now, it has been replaced by EGW because of the process improvements discussed above and because the side-shell plating of smaller ships is not sufficiently thick to effectively use ESW. The consumable guide ESW process remains useful for welding deck longitudinals providing their thickness exceeds about 35 mm.

Nippon Steel, in conjunction with Mitusoishi-Koyagi, has developed an automatic welding machine for L-type longitudinals. Called LONGIWELD, it welds the vertical portion by ESW and the horizontal portion by SAW in one continuous weld. The automatic switching from ESW to SAW is controlled by a slag depth sensor. A dam is used to control the SAW weld pool and a one-piece L-shaped copper backing bar is required.

Automatic GMAW equipment has been developed for shipyard applications, e.g., the Nippon Steel Oscillation Controlled (OSCON) process. However, the use of such equipment is quite limited. The reason appears to be that GMAW is regarded as a process that requires constant monitoring by an operator to avoid weld defects such as lack of fusion. Thus, the labor savings are minimal. The use of multiple GMAW machines for four-corner simultaneous vertical fillet welding of egg-box structures was every useful for building

supertankers which had very deep sections. However, the smaller ships now being built cannot take advantage of this technology because the weld lengths are too short.

- Robots

There are widespread efforts within Japanese shipyards to develop applications for robots. Large, fixed position robot systems are being used for the first stage of assembly immediately downstream from the plate cutting lines. For example, Mitsui-Tamano has one eight-axis robot for subassembly that uses a numerical control teaching method and an optical seamtracker. This robot was "on-line" but its use was still very much in the development stage. Large robot systems were also being developed at Hitachi Zosen-Ariake and the NKK Tsu Works.

Mitsui-Chiba is evaluating portable robots for plate-stiffener fillet welds. These welds are currently made by the gravity welding process, which is very difficult competition for the robot. My impression is that a great deal of effort has been made to find suitable applications for portable robots, but none were observed in production at any of the shipyards visited.

A few fixed position five-axis general purpose robots can occasionally be seen doing mundane welding tasks in the shipyard. This seems to be a "let's get used to them approach" rather than an important production tool. For example, Kawasaki-Sakaide is using a Unimation robot for cutting L-shaped sections; this can be done with a single continuous cut rather than the two normally required. Also Kawasaki was evaluating an apprentice robot for making the short vertical welds connecting longitudinals to transverse members. Kawasaki Heavy Industries first licensed robot technology from Unimation in 1968 and is a major supplier of industrial robots. Yet robots appeared to be of negligible importance to the shipyard.

Despite the low level of current usage, there does appear to be a commitment in Japan to develop robots for shipyard applications. Apparently this is part of a Ministry of International Trade and Industry (MITI) program to assist the shipbuilding industry in their efforts to compete against shipyards in countries such as Korea. However, the prevailing attitude that I perceived among the welding engineers is that robots have not contributed to production despite high level interest within their companies to use them. I suspect that after a few years of these trial-and-error efforts, important applications will be found for robots.

TRENDS IN STEELS FOR SHIPS AND OFFSHORE STRUCTURES

Remarkable changes have occurred in the use of steels for ships and offshore structures over the past several years. These changes have led to significant productivity improvements in shipbuilding and enabled the construction of offshore structures that meet severe design requirements. Developments in steels include the following:

- increased use of high strength steels for merchant shipbuilding,
- development of higher strength steels (45 and 51 ksi yield strengths) with the weldability of mild steel,
- extensive use of HT80 and other high strength steels in the construction of jack up rigs,
- development of steels for arctic structures that meet stringent toughness requirements at -60°C.

- High Strength Steels for Ships

The use of high strength steels in merchant ship construction has recently been surveyed by the Japan Shipbuilding Research Association [*ISSN* 0546-1480, (1984)]. Usage has been limited by several technical factors: buckling strength, fatigue strength, local strength, corrosion control, and cost of construction. Buckling strength and fatigue strength are not improved by an increase of tensile strength; however, improved design practices can more effectively use the higher strength steels. Local strength criteria are needed for application of high strength steels to internal structures. Corrosion control becomes more important as thickness is reduced. The increased cost of contruction associated with higher strength steels may be more than offset by thickness and weight reduction now that higher strength steels with improved weldability are available.

The use of high tension steel in bulk carriers can be described in terms of four categories as shown in Figure 2. During the 1970s, high strength steels were used primarily in the upper deck section (category one) and the strength level was limited to XH32 (45 ksi yield). During the 1980s, usage for bulk carriers in the 120 to 230x10^3 DWT-size range was extended to the bottom and inner bottom plating (category three) and in some cases to the side shell (category four). In addition, XH36 (51 ksi yield strength) steel was introduced into the upper deck section. The use of high strength steel in four bulk carriers built in the past year was discussed at Kawasaki-Sakaide. Two of three small bulk carriers (36x10^3 DWT), were in category four. The larger bulk carrier (130x10^3 DWT) was in category four, with extensive use of XH36 in the upper deck section and longitudinal T-sections throughout the midbody.

The four categories shown in Figure 2 are not directly applicable to other classes of ships, e.g., tankers usually have a single bottom. However, the categories are used below for simplicity. For oil tankers, category two was common throughout the 1970s with some use of high strength steel in the upper and lower sections of the side shell and in the longitudinal bulkheads. Strength levels were generally limited to XH32. Usage of high strength steels was typically 20-30%. Due to limited data, usage trends for tankers are not clear, but Kawasaki-Sakaide built a category four tanker with some XH36 this year. For ore carriers, both category one and two designs were used in the 1970s, with partial use of high strength steel in the side shell and the longitudinal bulkheads. Usage ranged from 11 to 27%. The ore carriers built in the 1980s have been one category three design and three category four designs (with 57-69% high strength steel). For container ships which are relatively small, the use of high strength steel remains limited to category one.

In summary, there is a general trend toward increased use of high strength steels in ship construction. The greatest impetus for this trend is the improved weldability of the higher strength steels produced by thermal mechanical controlled processing (TMCP). Now that the economics favor the use of high strength steels, it is likely that minor changes in design rules and strength criteria will lead to even greater usage. It is even possible that after 30 years or so with a 51 ksi limit on yield strength, a higher strength grade produced by TMCP may be proposed for shipbuilding. For example, NKK-Tsu received special approval from the American Bureau of Shipping (ABS) to use a 60-ksi yield strength steel for the barge used as a mud base for the concrete island drilling system.

- TMCP Steels for Shipbuilding

Thermal mechanical controlled processing (TMCP) is a continuous processing method for producing steel plates that have properties in the as-rolled condition that equal or exceed those of heat treated plates. For shipbuilding, the main advantage of TMCP is that

a lower alloy content is needed to meet the required levels of strength and toughness. Thus, the steels have a lower carbon equivalent and improved weldability. For high strength (XH32 and XH36) ship steels, the alloy content and weldability are equivalent to that of mild steel. Thus, the production controls formerly needed to weld high strength steels have been relaxed and significant improvements in productivity have been achieved.

A comparison of the welding procedures used for conventional steels versus TMT steels was provided by Mitsui Zosen for the case of EH32. Preheating is generally required for EH32, the level depending on the carbon equivalent, C_{eq}. In the case of TMT steels with $C_{eq} \leq 0.36\%$, preheat is unnecessary providing the temperature is over 0°C and low hydrogen electrodes (≤ 5 cc/100g) are used for butt welding. The minimum length of tack and repair welds can be reduced from 50 mm (for conventional steel) to 10 mm for TMT steel providing the C_{eq} is less than 0.34% and low hydrogen electrodes are used. The baking requirements to control hydrogen are relaxed in terms of baking temperature, holding temperature, and exposure time. The baking temperature is reduced from 300-350°C (conventional) to 70-100°C (TMT); a 30 to 60 min cycle is required in both cases. The holding temperature is reduced from 100-150°C to 70-100°C. The exposure time was increased from four to eight hours. Gravity welding, which is commonly used for fillet welding of subassemblies in the flat position, normally requires the use of low hydrogen electrodes, but with TMT steels ($C_{eq} \leq 0.36\%$), high hydrogen (≤ 30 cc/100g) electrodes can be used. Finally, the temperature limits on flame strengthening have been increased from 650 to 850°C when followed by air cooling to 600°C and then water cooling. Each of these changes reduces costs of ship construction with no sacrifice of quality. Apparently, similar results are being obtained by other shipyards and by the SR193 committee of the Japan Shipbuilders Research Association. As a result of these findings, the TMT steels have found broad acceptance by the shipbuilding industry over the past two years.

The main reason for the improved weldability of TMCP steels is the reduced carbon equivalent. Carbon equivalents for conventionally processed steels (normalized or controlled rolled) are typically 0.40 to 0.42% for TMCP steels. Types I and II have carbon equivalents in the 0.35 to 0.39% range and Type III has carbon equivalent in the 0.28 to 0.34% range. Here, TMCP Type I refers to control rolling at particularly low temperatures (i.e., below Ar_3); TMCP Type II refers to control rolling following a particularly low reheat temperature (950° to 1050°C), and TMCP Type III refers to control rolling followed by accelerated cooling.

Productivity benefits beyond those discussed above are also possible in the TMCP steels. Microalloying and fine chemistry control have led to the development of ship steels with remarkable tolerance to high heat inputs. In conventional steels, high heat input welding practices cause a deterioration in the toughness of the heat affect zone (HAZ). As a result, low heat input welding practices having reduced productivity must be used. In Japan, each of the steel plate producers have developed advanced steelmaking and microalloying techniques that limit grain coursening and embrittlement in the HAZ. For example, at NKK, steels with low nitrogen (<40 ppm), high aluminum (0.04/0.07%), and titanium (0.01%) retain satisfactory HAZ toughness for heat inputs to 250 kJ/cm. With this heat input, tolerance single-pass welding with high heat input welding processes, such as one-side SAW and electrogas welding, can be used for welding high strength steels.

- High Strength Steels for Offshore Structures

The high strength steels for semisubmersible offshore structures are similar to those used in ship construction, i.e., EH32 and EH36 in thicknesses typically under 51 mm.

Applications include virtually all parts of a semisubmersible, i.e., lower and upper hulls, columns and braces; however, overall usage in six designs (*JSRA, ISSN* 0546-1480) was only 31%. Jack-up rigs, on the other hand, make extensive use of high strength steels (51% usage in eight designs) and the strength levels go up to HT80 (tensile strength of 112 ksi). The HT80 steel is used in columns, and racks and HT60 along with some HT80 are commonly used in braces. High strength steels in the XH32 and XH36 classes are used for the platform and upper hull.

The HT80 steels are generally welded by low heat input, multipass, manual, or semiautomatic processes with preheats in the range of 125 to 190°C. For example, the Ariake Works of Hitachi Zosen uses SMAW for rack-to-rack and either SMAW or GMAW for chord-to-chord or chord-to-rack welds. Frequently, the first two passes are put in by the GTAW process to avoid root cracking. Preheats are 135°C for GMAW (hydrogen <0.8 g/cc) and 185°C for SMAW butt welds. Heat inputs are limited to 30 kJ/cm. The various T, K, and Y welds are made by the SMAW process using a preheat of 155°C. The chord-to-rack weld joint is simply loaded in shear and partial penetration welds are used; a mild steel backing piece is seal-welded by SMAW and then multipass SAW (39 kJ/cm, max) is used to fill the remaining 19 mm on each side of the double-V joint. The weld is made with Kobe US-80BN wire and MF38B, ultralow hydrogen flux. A 150°C preheat is required.

Higher productivity welding methods for jack-up rigs have been evaluated by the Tsu Laboratories of NKK. Weld procedures were developed and evaluated for a full-scale model of a column, rack, and cord assembly. The results summarized in Table I indicate that welds by the narrow gap GMAW process, the high current GMAW process, and conventional GMAW all met the 80 kg/mm² strength requirement and the 3.5 kg/m toughness requirement at -46°C in the weld, fusion line, and HAZ.

- Steels for Arctic Structures

The shipbuilding and steelmaking industries of Japan have identified arctic development as a major new business opportunity. Thus, extensive research and development programs are in progress to develop steels and welding procedures for steel structures with good practice resistance to temperatures down to -60°C. Recent projects include the mobile arctic caisson rig built at the Aichi Works of IHI, a conical drilling rig for icebound seas built at the Tamano Works of Mitsui, the concrete island drilling system built at the Tsu Works of NKK, and the *Shirase*, an antarctic observation icebreaker built at the Tsurumi Works of NKK. Related experience with low temperature structures includes the construction of LPG and/or NG carriers by several shipyards and extensive experience with structures for the North Sea, the North Atlantic, and the Gulf of Alaska. Design studies include platforms, semisubmersibles, and barges for oil exploration and operation, and icebreaking tankers for oil and LNG. The steel industry has responded with a variety of new steels with improved toughness at low temperatures in the as-welded condition.

Many of the high heat input welding practices have been qualified for low temperature service due to the exceptional weldability of the new accelerated cooled steels of the EH36 class. For example, the Ariake Works has qualified several procedures on 40 mm plates for service to -60°C, including SAW with heat inputs to 150 kJ/cm and pulsed-arc GMAW with heat inputs to 45 kJ/in. Work was in progress to develop one-sided (FCB) SAW procedures with heat inputs of 250 kJ/cm (35 mm plate) and electrogas welding (Kobe SEGARC-2) with heat input of 170 kJ/cm (25 mm plate) for service to -65°C. The Tsu Works of NKK has qualified several procedures for EH36 steel (32 mm plate) for

service to -60°C, including one-sided (FCB) SAW with long distance operation between electrodes, SAW with one pass per side, mixed gas (argon, 20% CO_2) GMAW, and SMAW.

A modified version of EH36 has been developed for use in arctic structures. The NKK version of EH36 Mod has been used for the upper barge of the concrete island drilling system built by the Tsu Works. The property requirements, aim chemistry, and steel processing are shown in Figure 3. The modifications over conventional EH36 are alloying with Cu and Ni, for low temperature toughness, tight control over Ti, N, and Al, for high heat input tolerance, and a lower level of S and C. Thermal mechanical processing is used to meet strength and toughness requirements; specifically, a low slab reheating temperature (1000-1050°C), intensified controlled rolling (70% reduction below 800°C), a finishing temperature above Ar_3 (>710°C) and accelerated cooling with a finishing temperature of 550°C. The resulting steel has a remarkable tolerance for high heat input welding. For example, a single-pass one-side weld can be made in 32 mm thick plate by the SAW process using flux copper backing. The heat input is in excess of 500 kJ/in. The test results indicate satisfactory fracture toughness is retained in the HAZ at -60°C.

Nippon Steel has also developed a modified EH36 steel for arctic service. The steel is specially processed to reduce the nitrogen level to below .0035 and Ti-B treated to improve HAZ toughness by intragranular ferrite percipitation (IFP). The addition of small amounts of Ti and B in a low N steel enhances the percipitation of IFP during weld thermal cycles and reduces the effective grain size in the HAZ. As a result, high heat input processes can be used and satisfactory toughness retained in the HAZ. Results for fusion line and HAZ toughness are summarized in Figure 4 [Ohno, Y. *et al.*, *Nippon Steel*, (1984)].

New grades of HT80 (100 ksi yield strength) steel have been developed for arctic applications. The specification for chemical composition and a typical chemistry for the NKK grade is shown in Table II. Note that the nickel content increases from about 2 to 4% as thickness increases from 38 to 180 mm. Special processing including ladle refining [see ONRFE *Scientific Bulletin*, *9* (2), 144 (1984)] is used to lower P to 0.005% and S to 0.001%. The steel is quenched and tempered to achieve the required strength and toughness. The welding conditions used to meet a 20 ft lb Charpy impact requirement in the weld; HAZ and fusion line are summarized in Figure 5.

SUMMARY COMMENTS

Advances in the welding technology used in Japanese shipyards have been limited over the past ten years. However, numerous changes in welding practices have been made to improve productivity and to accommodate changes in design requirements for ships and offshore structures. The principal changes in welding practices are the increased use of semiautomatic welding by the mixed gas GMAW process and the CO_2 FCAW process, and the development and widespread use of a fine wire, lower-heat-input version of electrogas welding.

Ship steels have been remarkably improved over the past ten years. Thermal mechanical control processing (TMCP) has permitted the reduction of alloy content (carbon equivalent), and consequently decreased susceptibility to cold cracking. Thus, preheating can be eliminated in most cases and hydrogen controls can be relaxed. A second improvement in ship steels is the development of low nitrogen (<0.004% N) steels which are microalloyed to provide tolerance to high heat input welding. These new steels have contributed to the increased use of high strength steels in ships and to the development of structures for the arctic.

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The author had the opportunity to visit numerous shipyards and associated laboratories where current welding practices and future trends could be observed. The observations and discussions during the visits and the technical information received in the form of reports and papers from these organizations form the basis of this report. The author particularly appreciates the generous assistance received from Mr. Koki Tachibana, Special Technical Adviser of the American Bureau of Shipping, Tokyo office. The author also extends thanks to the following individuals and their colleagues for their generosity, patience, and competence during my visits to their organizations.

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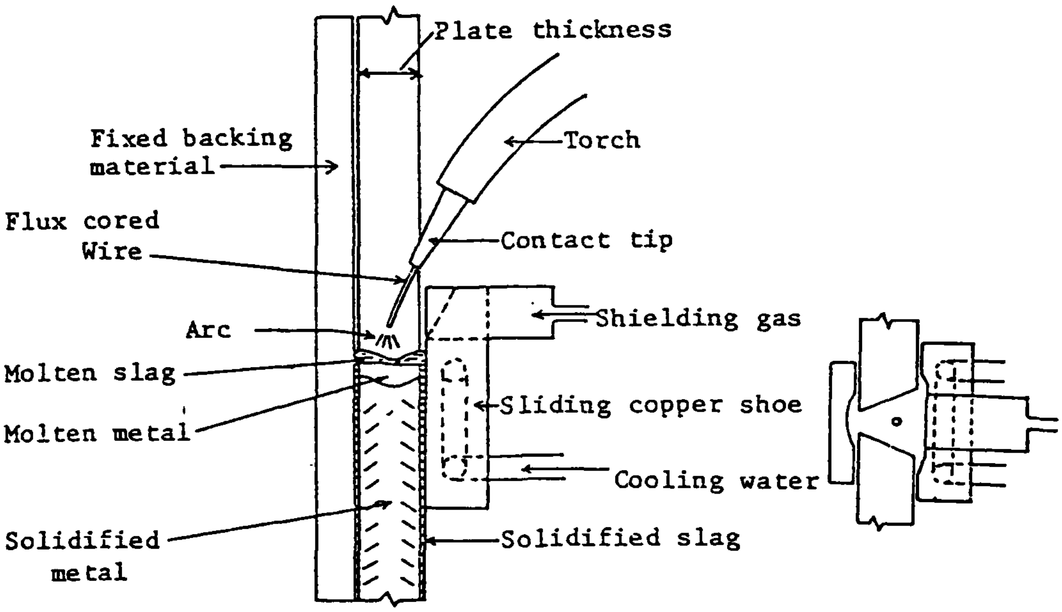


		T	3/8 inch (9mm)	1/2 inch (12mm)	5/8 inch (16mm)	3/4 inch (19mm)	7/8 inch (22mm)	1 inch (25mm)
		A	1/4 inch (6mm)	1/4 inch (6mm)	3/16 inch (5mm)	3/16 inch (5mm)	3/16 inch (5mm)	3/16 inch (5mm)
		θ	60°	50°	45°	40°	40°	35°
Welding Consumables	Wire		DWS-43G 1/16 inchø (1.6mmø)					
	Shield gas		100% CO_2 60 ft^3/Hr (30 liter/min.)					
	Backing material		Water-cooled copper backing		KL-4GT (Water-cooled copper backing)			
Welding Conditions	Current		350A	350A	380A	380A	380A	380A
	Voltage		34V	34V	34V	35V	36V	37V
	Speed		5.3 inch/min. (13.5 cm/min.)	4.5 inch/min. (11.5 cm/ in.)	3.9 inch/min. (9.9 cm/min.)	3.2 inch/min. (8.1 cm/min.)	2.8 inch/min. (7.0 cm/min.)	2.3 inch/min. (5.9 cm/min.)
	Wire stickout		1 1/4 ~ 1 1/2 inch (From tip end to base metal)					
	Heat input		135 KJ/inch (53 KJ/cm)	157 KJ/inch (62 KJ/cm)	198 KJ/inch (78 KJ/cm)	251 KJ/inch (99 KJ/cm)	297 KJ/inch (117 KJ/cm)	363 KJ/inch (143 KJ/cm)
Mechanical Properties of All Deposited Metal	Yield point		67000 lbs/in² (47.0 kg/mm²)	67000 lbs/in² (46.9 kg/mm²)	58000 lbs/in² (40.9 kg/mm²)	56000 lbs/in² (39.5 kg/mm²)	55000 lbs/in² (38.9 kg/mm²)	57000 lbs/in² (40.4 kg/mm²)
	Tensile strength		83000 lbs/in² (58.6 kg/mm²)	80000 lbs/in² (56.1 kg/mm²)	79000 lbs/in² (55.5 kg/mm²)	77000 lbs/in² (53.9 kg/mm²)	78000 lbs/in² (54.9 kg/mm²)	74000 lbs/in² (52.0 kg/mm²)
	Elongation		29%	26%	28%	27%	27%	28%
	Reduction of area		68%	66%	69%	72%	70%	59%
	Impact value at 0°C		44.0 ft·lbs (6.1 kgf-m)	79.4 ft·lbs (11.0 kgf-m)	65.7 ft·lbs (9.1 kgf-m)	62.1 ft·lbs (8.6 kgf-m)	62.8 ft·lbs (8.7 kgf-m)	54.1 ft·lbs (7.5 kgf-m)

Figure 1. The SEGARC Process for Electrogas Welding.

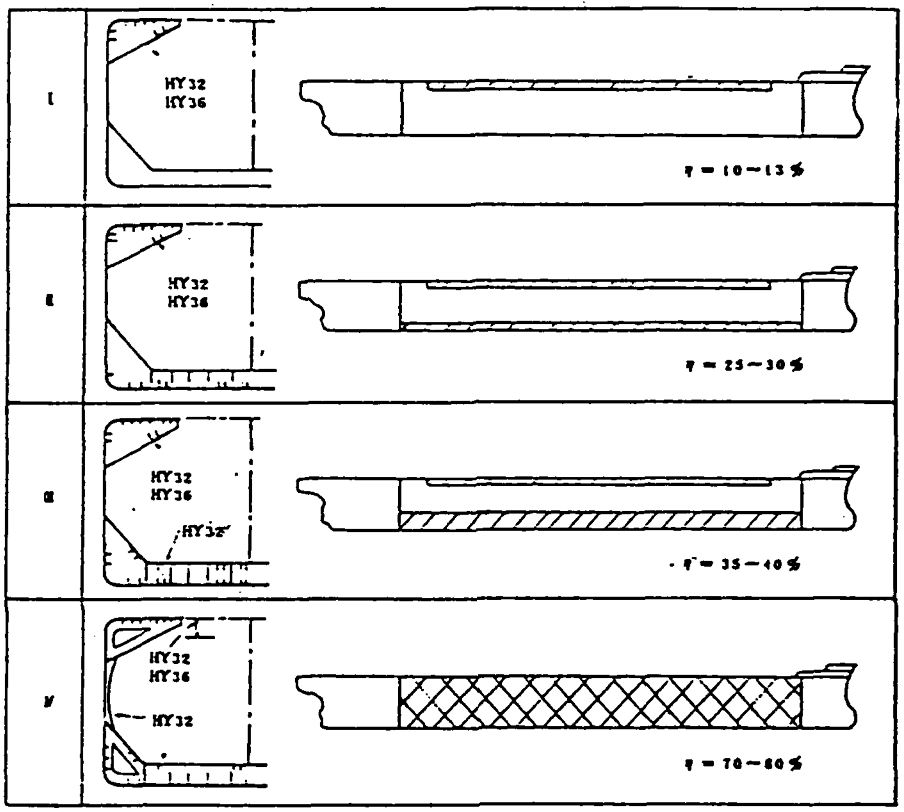
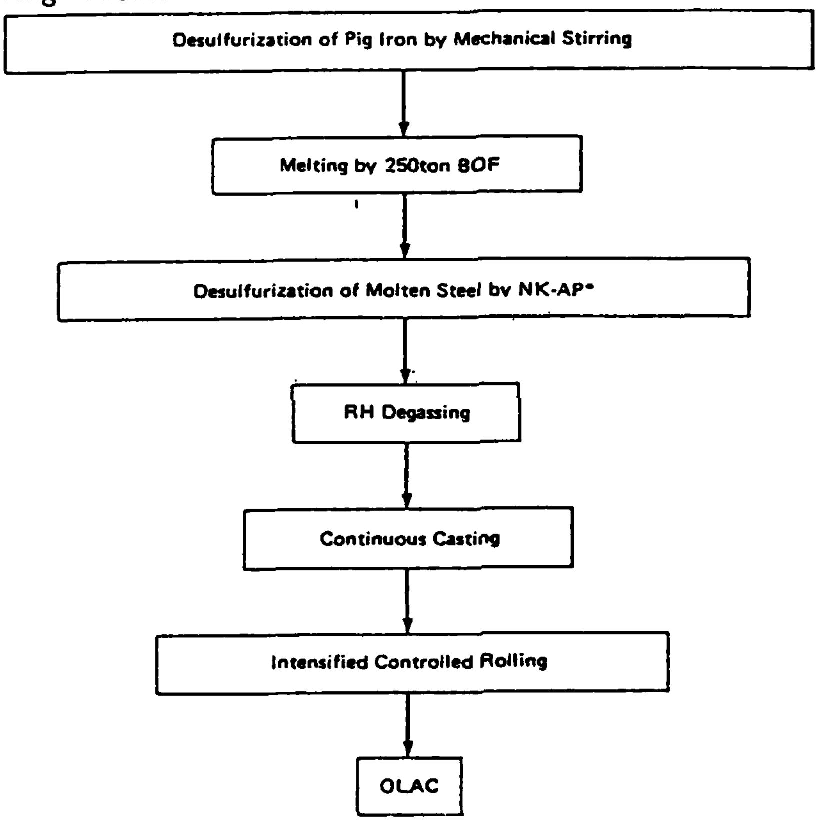


Figure 2. Usage categories for high strength steels in bulk carriers. Shaded area (lengthwide section) and dash lines (cross section) represent high strength steels.

Property Requirements

Properties	Requirements
Strength	Equivalent to EH36 steel plates for shipbuilding min. YS of 353 MPa (36.0 kgf/mm^2) min. TS of 490 MPa (50.0 kgf/mm^2)
Toughness	Min. CVE of 34 J (3.5 kgf·m) at −60°C in both base plates and weldments. (Preferably at high heat input)
Weldability	Max. CE of 0.38 to 0.40 % and under. (Preferably preheating-free)

Manufacturing Process



*NKK ArcProcess

Aim Chemistry

C	Si	Mn	P	S	Cu	Ni	Ti	Sol.Al	T.N	CE
0.07	0.30	1.50	0.020 max	0.002 max	0.20	0.35	0.007	0.060	0.004 max	0.36

Figure 3. Property requirements, manufacturing process, and aim chemistry for an arctic grade EH36 Modified Steel, [*Nippon Kokan* (NKK) (1984)].

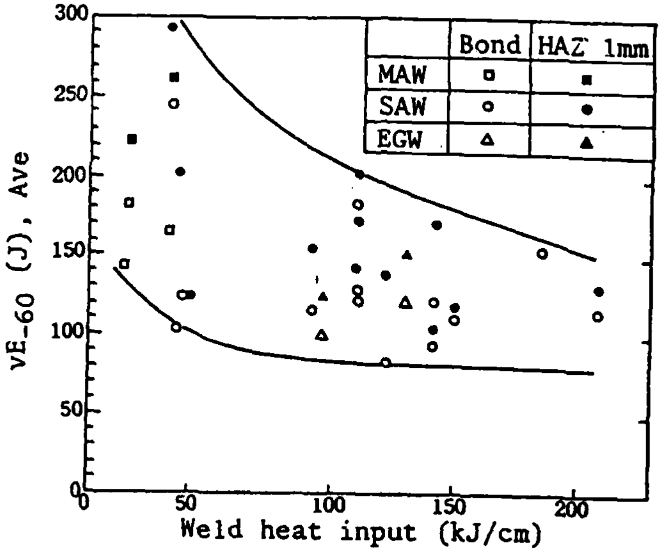
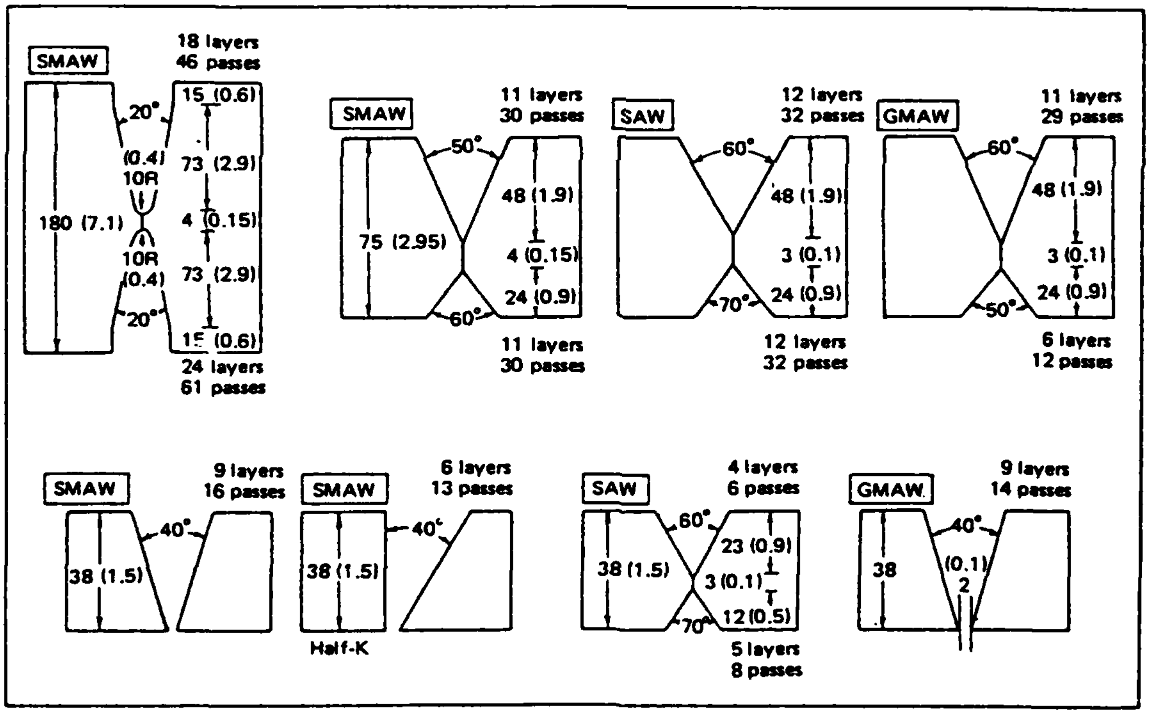


Figure 4. Relationship between weld heat input and V-Charpy absorbed energy at -60°C for welded joints of EH36 Mod-type steel for arctic service [Ohno, Y. *et al.*, *Nippon Steel*, (1984)].

Thickness mm (in)	Welding process	Welding position	Welding material	Welding conditions	Heat input kJ/mm (kJ/in)	Preheat & interpass temp. °C (°F)
180 (7.1)	SMAW	Vertical-up	7887P(1)	150A – 24V –70 mm/min.	3.0 (76)	125 & 125-150 (257) (257-302)
38, 75 (1.5)(2.95)	SMAW	Vertical-up	7887P(1)	150A – 24V –70 mm/min.	3.0 (76)	125 & 125-150 (257) (257-302)
	SAW	Flat	7875 +(2) PFH80N	600A – 30V –300 mm/min.	3.5 (89)	125 & 125-150 (257) (257-302)
	GMAW	Vertical-up	MGS80(3) Ar + 10%CO_2	140A – 22V –90 mm/min.	2.0 (51)	125 & 125-150 (257) (257-302)

Note: (1) AWS A5.5 E1106-G
(2) AWS A5.23 F12A10-EG-G
(3) AWS ER110S-G



Dimension; mm (in)

Figure 5. Welding conditions and edge preparations for welding HT80 steel--NK-HITEN 80 CLT--for service to -76°C. [*NKK* Tec. Doc. No. *243-035*, (1984)].

TABLE I

WELDING PROCEDURES DEVELOPED FOR THE HT80 LEG STRUCTURE OF A JACK UP RIG (NKK-TSU)

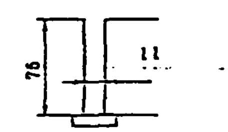
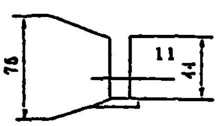
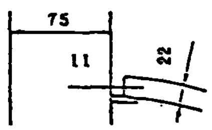
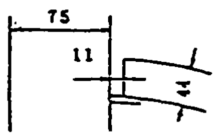
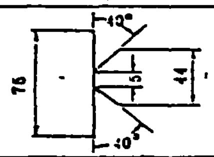
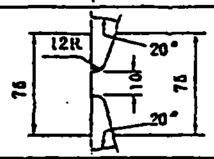
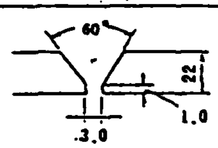
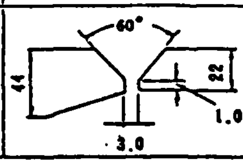
Welding process and condition	Mark of joint	Edge preparation	Heat input kJ/cm	Impact test at −46°C (2 mm V-- notched Charpy specimen)		
				Notch location	Absorbed energy Kg.m	Crystallinity %
Narrow gapped GMAW (Single electrode) ① Wire diameter : 1.2 mm ② Welding condition Welding current 260～285A Arc voltage 29～31V Travel speed 16～22 cm/min ③ Shield gas Ar + 20% CO_2	Rack to Rack		21.4 ～22.0	WM Bond＊＊＊ HAZ	7.5 9.5 14.5	42 48 10
	Chord to Chord		20.6 ～21.3	WM Bond HAZ	5.6 5.5 10.9	32 62 15
	Rack to Column		16.2 ～20.6	WM Bond HAZ	4.4 9.5 9.6	60 27 38
	Rack to Column		16.2 ～21.7	WM Bond HAZ	4.3 5.5 9.8	40 58 25
Large current GMAW (Single electrode) ① Wire diameter : 4.0 mm ② Welding condition Welding current 750～850A Arc voltage 29～30V Travel speed 25～45 cm/min ③ Shield gas Ar + 20% CO_2	Rack to Chord		29.0 ～51.0	WM Bond HAZ	10.7 9.0 10.9	27 23 27
	Rack to Chord		43.5 ～54.0	WM Bond HAZ	4.9 5.6 6.5	65 50 60
Conventional GMAW ① Wire diameter : 1.2 mm ② Welding condition Welding current 180～190A Arc voltage 19～20V Travel speed 4.5～8.0 cm/min ③ Shield gas Ar + 20% CO_2	Column to Column		25.7 ～50.6	WM Bond HAZ	4.1 5.6 4.4	70 42 53
	Column to Column		25.7 ～50.6	WM Bond HAZ	4.1 5.3 3.5	68 60 55

TABLE II

CHEMICAL COMPOSITION (wt.%) OF HT80 STEEL--NK-HITEN 80CLT--
FOR SERVICE TO -76°C

Thickness mm(in)	Chemical composition*											
	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	V	B	C_{eq}**
Specification Maximum Values	0.16	0.35	1.20	0.020	0.020	0.50	4.00	1.00	0.60	0.10	0.003	-
180 (7.1)	0.12	0.10	1.04	0.004	0.001	0.24	3.74	0.76	0.43	0.04	0.001	0.65
75 (2.95)	0.12	0.07	1.05	0.005	0.001	0.23	2.67	0.75	0.39	0.04	0.001	0.62
38 (1.5)	0.11	0.08	1.03	0.005	0.001	0.25	2.16	0.67	0.38	-	-	0.57

* Sampling position is mid-thickness

** $C_{eq} = C+Si/24+Mn/6+Ni/40+Cr/5+Mo/4+V/14$

MARINE SCIENCE IN NEW ZEALAND GOVERNMENT LABORATORIES

Wayne V. Burt

INTRODUCTION

New Zealand, with a land area of only 266,000 km² (103,000 mi²), is a little smaller than the state of Colorado. Its population in 1980 was only 3,155,000, very close to the population of the state of Connecticut. The country consists of the two large islands and a dozen or so much smaller islands. Although they are insignificant in size, seven of these islands are strategically placed around the main islands in such a way as to give New Zealand the fourth largest 200 mile oceanic exclusive economic zone (EEZ) of all the countries in the world (See Figure 1). New Zealands's EEZ is fifteen times as large as its land area. The Challenger Plateau to the northwest, the Chatham Rise to the east, and the very extensive Campbell Plateau to the southeast are relatively shallow. The area within the EEZ with depths less than 500 m (somewhat less than the depth from which oil is presently being recovered elsewhere) is over twice the land area of New Zealand. Thus the country has a very large shallow submerged sea floor within its EEZ that is potentially exploitable for minerals, hydrocarbons (gas and oil), and for enlarging its fishing industry.

New Zealand's principal exports are wool, meat, dairy products, manufactured goods, and forestry products in that order. Other than food, wood, and iron ore, most of the raw materials and much of the manufactured goods that the country requires must be imported. Thus the country's economic health is primarily dependent on the fluctuating prices of their agricultural products on the world's markets. Diversification in sources of income and raw materials is needed. For this reason, New Zealand is increasing its investment in research on the potential exploitation of the shallow seas around it.

An example of one major problem and its possible solution is the use and source of a supply of phosphate fertilizer to keep its pastures green. New Zealand has the highest per capita use of phosphate of any country in the world. The one million tons of phosphate ore that are used each year are all imported from the rapidly dwindling deposits of phosphate on Christmas and Nauru Islands. Cooperative United States-New Zealand and New Zealand-German research programs on Chatham Rise have respectively found and defined the extent of deposits of phosphate ore, in the form of nodules, at depths around 400 meters. Present estimates suggest that this source of phosphate could meet New Zealand's needs for many decades.

For the size of its population, New Zealand has one of the largest marine science centers in the world. It is the capitol city of Wellington on the north shore of Cook Strait that separates the two main islands. The center consists of the Fisheries Research Center (FRC) of the Ministry of Agriculture and Fisheries, and the New Zealand Oceanographic Institute (NZOI), a part of the Division of Marine and Freshwater Science (MFS) of the Department of Scientific and Industrial Research (DSIR).

The 2.5 ha (6.2 a) location of the center is on Greta Point on the eastern edge of the city. It is on the seaward side of Evans Bay Parade. The center's location gives it high quality sea water that is uncontaminated by surface runoff, storm water, sewage, or industrial pollutants. There is adequate land for buildings, operational areas, public recreational facilities, and some further expansion of the center's facilities. It is located on deep water only a few minutes steaming time from Cook Strait and has nearby

direct access to the Pacific Ocean to the east and via the strait to the Tasman Sea between New Zealand and Australia to the west.

A mixed blessing of the Greta Point site is its surfeit of bracing fresh air. According to an article by Derek Wilson, the architect, in the third issue of the magazine, *Architect for 1983*, which gives a detailed description of the physical plants of NZOI and FRC; on the seaward edge of the site the wind gusts to 17.5 m/sec (34 km) or more on an average of 188 days a year. Aside from the need of a chin strap on your hat, this is one of the most beautiful sites of any marine science center in the world.

The FRC and some of its research activities will be discussed first, followed by more extensive discussion of NZOI and its research activities.

THE FISHERIES RESEARCH CENTER

The Fisheries Division of the government was established in 1965 and in 1973 became a part of the Department of Agriculture which is now the Ministry of Agriculture and Fisheries. The Fisheries Division now has a staff of 200, of which 120 are stationed at the FRC in Wellington. Their Greta Point Laboratory was officially opened in September 1982 after a long period of gestation (it was commissioned in 1970 and its environmental impact statement was completed in 1974). The attractive, extensive, well-designed physical plant was well worth waiting for.

FRC has 6970 mi^2 (75,000 ft^2) of covered floor space consisting of a large laboratory building, library, cafeteria and conference center, workshops, storage and boat sheds, and garage. There are outside areas with experimental ponds and tanks and staging areas. FRC is charged with research projects leading up to improvements in management, conservation, and exploitation of all of New Zealand's fresh water and marine fisheries resources.

The marine fishing industry of New Zealand has increased enormously during the past decade, particularly since the establishment of the EEZ in 1978. The fishing fleet used to consist of small boats between 40 and 60 feet in length that spent most of their time fishing in bays, estuaries and near shore areas, supplying fish to local markets.

Now New Zealand is encouraging joint ventures between foreign countries with large fishing vessels and open ocean fishing experience and major New Zealand companies without previous experience in the field. Some foreign companies just pay fees for the privilege of exploiting fisheries in New Zealand's EEZ but they have a better chance to operate in New Zealand waters if they are working with New Zealand based companies. The largest fishing trawler that I have ever seen was tied up alongside the Wellington-Picton ferry dock. It was a Russian ship. An export trade in fisheries products has started, particularly with the Orange Roughy, a high-priced luxury fish.

FRC operates the 42 m MV *James Cook* and the 28 m *Kaharoa* for shallow water and mid-depth fisheries research. In the absence of a deep-water fisheries research vessel of their own, the center has used foreign fishing vessels, including Russian ships, for research and collects data from foreign ships operating within their EEZ. The aim is to provide proper management of fisheries resources and to establish a stable industry which the government believes will contribute to New Zealand's economic well-being.

THE NEW ZEALAND OCEANOGRAPHIC INSTITUTE

The new facilities for the New Zealand Oceanographic Institute of Oceanography are located on Greta Point adjacent to the Fisheries Research Center because of their joint interest in many aspects of the marine environment around New Zealand. This allows mutual use of each other's facilities on the campus.

My principal interview during my visit was with the director of the NZOI, Dr. D. E. Hurley, a marine biologist. NZOI was established in 1954. It now has a permanent staff of about 50, plus varying numbers of visiting scientists, graduate students from universities doing research on their theses, and temporary and part-time employees. It is a part of the Division of Marine and Freshwater Science of DSIR with a total staff of nearly 70. The four scientific sections are:

- physical oceanography with six scientists,
- biological oceanography with eleven scientists,
- marine geoscience with eight scientists,
- and the recently added Taupo Research Laboratory (TRL) with nine scientists.

Fifty of the 70 permanent staff members of NZOI are located in Wellington. The remaining 18 permanent staff members are stationed at TRL on Lake Taupo, 240 miles north of Wellington.

The new NZOI facilities in Wellington were commissioned in 1967 and officially opened in August 1981. There are 3590 m^2 (35,630 ft^2) of floor space, most of which is in a large three-story office and laboratory building. A much smaller one and one-half story service building contains workshops, storage areas, small boat storage and repair facilities, and a garage. Expansion plans call for adding a large library wing to the main building and doubling the size of the service building.

Prior to 1973, NZOI used ships from the New Zealand Navy as well as chartered vessels for marine research. From 1973 on, it had been the principal user of the government research vessel, *Tangaroa*, which is 68 m (223 ft) long. This commodious converted freighter was owned by DSIR and operated by the Ministry of Transport. It carried a crew of 21 and had accommodations for six scientists. It spent an average of 225 days a year at sea. NZOI scheduled its use and used it over three-quarters of the time. It was also used by other DSIR divisions, universities, museums, and other government agencies, but since my visit to New Zealand the *Tangaroa* has experienced structural problems and is to be decommissioned.

The wide-ranging *Tangaroa* operated in the region from the Cook Islands, far to the northwest, and the subarctic slope near Antarctica to the south. It supported both national and international programs and regularly carried scientists from foreign countries who were visiting New Zealand under exchange agreements. On occasion, it had delivered urgent freight and mail to some of New Zealand's far-flung tiny islands.

The research efforts of NZOI are divided about equally between basic and applied research. The laboratory works closely on a cooperative cost sharing basis with other government agencies and local authorities, particularly harbor authorities, on problems that require oceanographic input. Research on marine problems for private industry is done on a cost basis. Altogether, about 90% of the funds supporting NZOI come directrly from the national government.

Dr. R. A. Heath, section head of the physical oceanography section, is also a deputy director of MFS. This section was first concerned with a general survey of the major mean currents around New Zealand, based on standard geostrophic calculations using routine surveys of the distribution of temperature and salinity. It was found that the eastward flow from the East Australian current splits and flows around both sides of New Zealand as two coastal currents, meeting and flowing eastward in the latitude of the Chatham Rise.

Studies of coastal tidal records showed the M2 semidiurnal lunar component is dominant. Any given phase moves continuously around the islands in a counterclockwise direction, producing high water on one side of the islands at the same time as low water on the opposite side. The phase difference across Cook Strait between the two main islands produces very strong turbulent semidiurnally alternating currents through the Strait with maximum current speeds at or near the time of high slack water on one side of the strait and low slack water on the other as the water flows downhill from one side to the other.

Daily water temperatures and weekly surface salinities are being measured at 16 coastal sites to provide climatic information on seasonal and interannual variability in coastal water masses around New Zealand. Currently, deep ocean research includes a study of the southern Tasman Sea and eddies in the Antarctic Circumpolar Current in the southeast Pacific.

An educational problem is being developed for civil defense organizers and the general public concerning a tsunami warning system. Wave refraction along underwater ridges and rises radiating outward from New Zealand focuses tsunami (tidal wave) energy at some locations along the coast and tsunamis set up seiches in some of the bays and estuaries.

The physical oceanographers are now concentrating most of their efforts in continental shelf problems with particular emphasis on areas off the west coast of South Island, Cook Strait, and Chatham Rise to the east of New Zealand. Studies include currents, tides, and long waves on the continental shelf and slope, mixing and upwelling, eddy structures, and physical processes in selected estuaries. Particular emphasis is placed on temporal variability. Increasing use is being made of current meters, and remote sensing data.

Heath's group is working very closely with the biological section on interdisciplinary physical/biological studies related to productivity, with the aim of developing models to study the various physical, chemical, and biological processes that control the variability of primary productivity. Special emphasis is being placed on the fertile coastal area on the west coast of South Island. Underwater troughs, ridges, plateaus, islands, sea mounts, straits, variations in the coastline, and strong variable surface wind stress all contribute to an unusually complicated regime of variability in physical oceanographic processes in the waters around New Zealand. Heath's research in the above complex area of study has been unusually productive. He and his coauthors have published over 60 scientific papers on the subject along with a number of less formal contributions since 1968. (See *Miscellaneous Publications of NSOI*, No. *98.*)

Dr. Janet M. Bradford is section head of the biological oceanography section, the largest section in NZOI. Over half of the scientists in the section are working in marine benthic ecology and closely related subjects. The objectives of the research in benthic ecology are to study the distribution, abundance, and identity of benthic species in the

New Zealand Exclusive Economic Zone in relation to their environment and importance in the marine food web. Initial emphasis is being placed on publishing distribution charts of dominant species and correlating benthic community structure with environmental factors. Many benthic organisms are either a food source for bottom-feeding fish, a potential or actual resource, or may contain pharmocologically important substances.

The other subject receiving major attention in the section is the study of the nutrient supply, primary productivity, and the transfer of energy through the food web to animals and plants that are now, or may be, of economic importance. The most recent estimate of the economic potential of marine food products to the economy of New Zealand is a quarter of a billion dollars a year (U.S. $160.0 million).

Interest and research in primary productivity has grown rapidly since the astronauts in Skylab 4 reported widespread blue-green streaks and blotches on the ocean surface east of New Zealand in 1973 and 1974. These sightings were indicative of unusually high phytoplankton concentrations for offshore waters. Dr. Bradford's subsequent literature search from publications from other countries on the distribution of nutrients, phytoplankton, and zooplankton in the New Zealand EEZ confirmed that there is a large variability in time and space in primary productivity in the waters around New Zealand.

Cooperative studies with the physical oceanographers have begun to show indications of relationships between orographically induced control of water movements and indicators of productivity. Semipermanent eddies, upwelling areas, rates and depths of vertical mixing in the near surface mixed layer, and movements of water across the continental shelf are all under study.

Dr. D. J. Cullen was head of the marine geoscience section. (Dr. Cullen has relinquished this position which is now occupied by Dr. K. B. Lewis.) In Dr. Cullen's absence, I interviewed Dr. L. Carter. This section carries out research and advises government agencies and private business on the geological and geochemical aspects of the sea floor around New Zealand and its estuaries, lakes, and reservoirs. Its primary interest is within the EEZ, but its studies range from the tropics to Antarctica. Prior to the past decade, the section had devoted most of its efforts to basic exploratory research, consisting largely of reconnaissance mapping. More recently it has been involved in applied research based on earlier findings.

Past and present offshore sea floor mineral investigations include:

- the distribution, analysis, and evaluation of manganese nodules,
- sulphide and oxide ores containing industrially important metals that are found along sea floor spreading axes,
- glauconite that may be used as a water softener and fertilizer,
- sand and gravel,
- near shore iron sand deposits, and
- phosphorites.

The only marine minerals that are presently being exploited are high grade silica sands that are mined in shallow harbors. The only other minerals that have commercial prospects at the present time are the phosphorite deposits on Chatham Rise. Exploitation of these deposits has reached the stage where a commercial license to mine them has been issued. The most recent estimate of the potential value of these deposits is NZ $10.0 billion (U.S. $5.6 billion).

The geoscience section has collaborated in a survey for minerals and precious coral sponsored by the UN-associated agency CCOP/SOPAC (Committee for Coordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas) in the EEZ's of Tonga, Samoa, and the Cook Islands.

Environmental studies in harbors, estuaries, fjords, lakes, reservoirs, and shallow inshore waters now make up a considerable portion of the section's activities. Advice is given to other governmental agencies and private businesses on:

- correcting natural deposition or erosional problems,
- the possible detrimental effects of disturbing sedimentary environments,
- the control of offshore waste disposal, particularly the disposal of dredging spoils outside of harbors,
- the placement of underwater pipelines, cables, and man-made structures on the sea floor,
- aspects of coastal and shallow water sea floor stability,
- sedimentation in lakes and reservoirs,
- and the dredging of harbor channels.

Side-scan sonar is used to study micro relief of the bottom in inshore waters and to locate lost items on the bottom.

In the 1950s, NZOI began a program surveying and charting water depths in lakes, coastal waters, and the ocean in the waters surrounding New Zealand and in the southwest Pacific. The Hydrographic Branch of the Royal New Zealand Navy produces navigational charts. NZOI compiles data on water depths from all available sources and carries out bottom depth surveys using small launches in lakes and shallow coastal waters, and the *Tangaroa* in oceanic areas with depths over 100 m. Those data are the basis for developing bathymetric charts. These bathymetric charts are used as research tools in locating and studying fault lines and other geological structures on the sea floor and as base maps for plotting distribution of bottom sediments, marine fauna and flora, and water mass properties. Commercially, the charts are used in exploration for oil and gas and for locating new fisheries areas.

Most of the bottom topography of New Zealand's continental shelf and slope have been mapped in detail. The coastal series of charts with a scale of 1:200,000 are in two subseries. One nearly complete series of 37 charts shows the bottom topography. A second series covering the same areas as the coastal bathymetric charts shows the distribution of bottom sediments. About a quarter of the charts in this series have been completed.

A second ambitious series of 72 proposed oceanic bathymetric charts, with a scale of 1:100,000 is well underway. When completed, these charts will cover the area from 145° E longitude to 143° W longitude and from 6° S latitude near the equator to 67° S latitude near Antarctica. About two dozen charts in this series have been completed, including those covering most of New Zealand's EEZ, several near Antarctica, and several around islands located to the north and northeast of New Zealand. In addition, bottom sediment distribution charts of areas within New Zealand's EEZ have also been completed. Compilation of second editions of some of the bathymetric charts is underway. Fathom-based charts are being metricated and have been redrawn, using new data based on modern, highly accurate methods of navigation.

THE TAUPO RESEARCH LABORATORY

Dr. W. White, officer-in-charge of the Taupo Research Laboratory, is also a deputy director of MFS. The recent amalgamation of the two laboratories into one division under one director enhanced the water chemistry and productivity expertise of the oceanography programs in NZOI and fostered the introduction of oceanographic techniques in the study of physical and geophysical processes in New Zealand's lakes.

I did not have an opportunity to visit the Taupo Research Laboratory of MFS. However, an examination of specialities of the staff indicated that they have considerable expertise in the study of nutrient budgets and cycling, primary productivity, population dynamics, and pollution problems in lakes and reservoirs.

I was very well impressed with the individuals that I interviewed at NZOI, the educational backgrounds of the staff, the facilities, and the scientific output as judged from lists of scientific publications and recent progress reports. For its size, the institute compares favorably with any marine science laboratory in the world.

The author would judge that the quality of life in New Zealand may be in part responsible for drawing talented scientists to NZOI. Many have had doctoral training in prestigious overseas universities, including the Massachusetts Institute of Technology (MIT), the University of California, Dalhousie University, Cambridge University, London (five persons), Vancouver University, University of Durham, Belfast University, and Bristol University.

The director of NZOI has room for visiting marine scientists from overseas countries who have their own sources of financial support for their research. The author highly recommends NZOI as a place for qualified persons to take a sabbatical leave. For further information write:

Dr. D. E. Hurley, Director,
Box 12-346
New Zealand Oceanographic/MFS Institute,
Wellington, New Zealand.

OCEANOGRAPHY AT THE DEFENSE SCIENTIFIC ESTABLISHMENT

The research program of the Royal New Zealand Navy is located within the Auckland Naval Base in Devonport, a short ferry ride across the harbor from downtown Auckland. The program was begun by the New Zealand Naval Research Laboratory in the early 1950s but the activities of the laboratory were subsequently incorporated into an organization called the Defense Scientific Establishment (DSE) following the reorganization of Defense in the late 1960s.

DSE operates HMNZS *Tui*, a 208-foot former U.S. Navy AGOR (*Charles H. Davis*) that was leased to New Zealand in 1970. The ship has a crew of 39 persons and has accommodations for nine scientists. The ship is primarily used for underwater sound propagation research and to a lesser extent for physical oceanographic research in support of underwater acoustics.

The *Tui*, buoys, and acoustic devices of the DSE are also used by the acoustics group in the physics department of the University of Auckland in cooperative programs to

obtain data for developing models to describe sound propagation in shallow continental shelf waters.

The author discussed the DSE's oceanographic research program with Dr. K. M. Guthrie, Mr. R. N. Denham, Mr. F. G. Crook and Mr. P. H. Barker. Most of their research has been concentrated in the areas around North Island and to the north of New Zealand in the South Fiji Basin and northern part of the Tasman Sea. Expendable bathythermographs (XBT's) are used to record water temperatures from the surface down to a depth of 450 m. Surface water samples are taken at each XBT station and used to determine the salinity at the surface. Observations at greater depths are made using a Neil Brown CTD profiler. Observations are made from both the *Tui* and RNZN frigates on passage through areas of interest.

Several long cruises have been made between North Island and the Fiji Islands. Data from these cruises indicate the presence of a persistent subsurface thermal front between 25° S and 26° S at depths between 100 and 400 m. The temperature cross sections constructed from the XBT observations also reveal the presence of weak eddies.

Several cruises have been made across the Tasman Sea in west to northwest directions between the northern tip of North Island and Australia. Temperature cross sections from these cruises show the presence of the "Tasman" front, a permanent subsurface meandering front that extends to the surface in winter.

XBT data from several local area cruises which crisscrossed the waters northeast of North Island have indicated the presence of a peculiar eddy structure. Two semipermanent warm core, counterclockwise eddies or meanders, about 200 km in diameter, are separated by a somewhat smaller cold clockwise eddy. These three adjacent features are probably orographically indicated into the mean coastal current that flows to the south over the uneven bottom topography in the region.

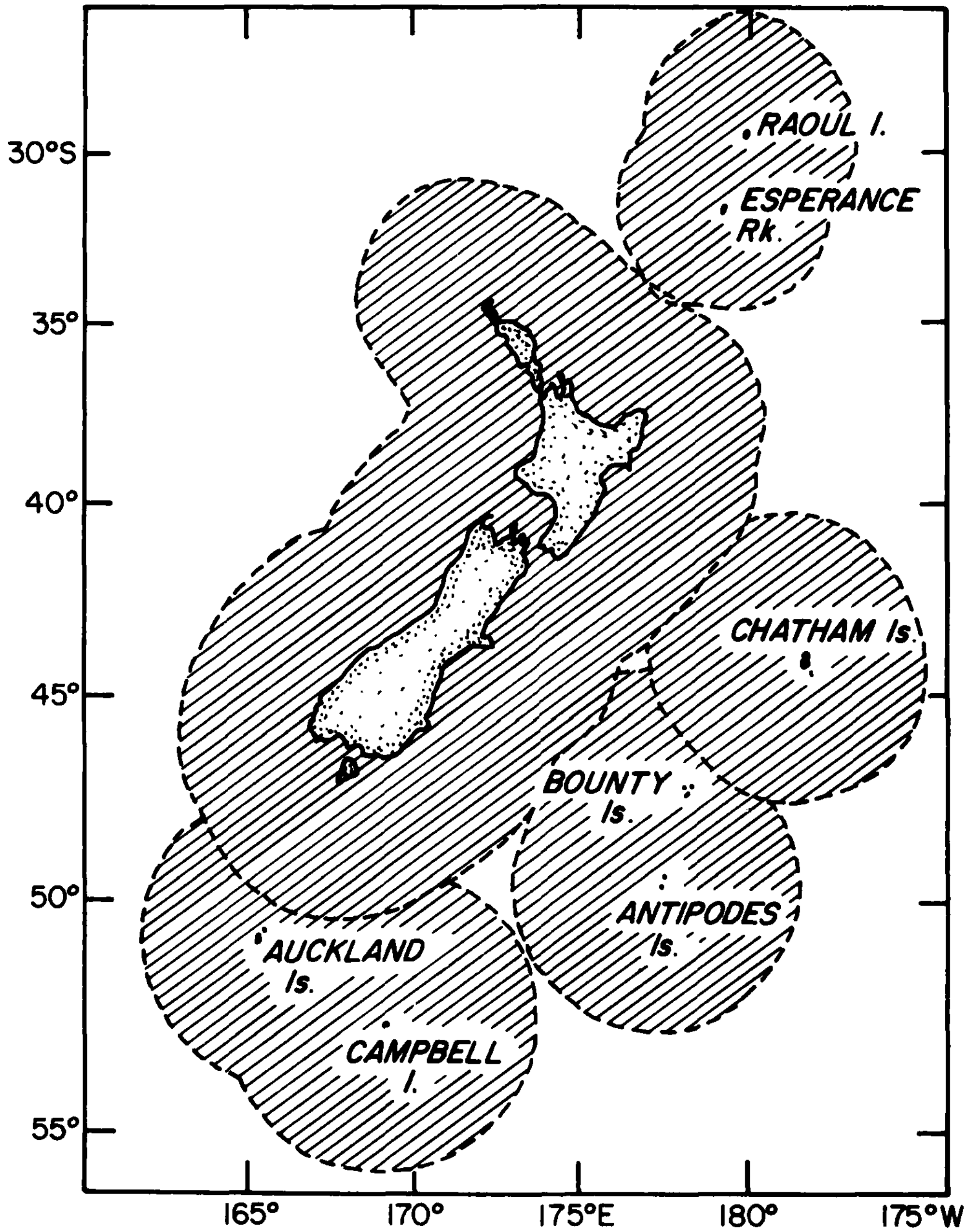


Figure 1. New Zealand's Exclusive Economic Zone

THE SIXTH AUSTRALIAN ELECTROCHEMISTRY CONFERENCE AND VISITS TO SELECTED AUSTRALIAN UNIVERSITIES AND INSTITUTES

Gleb Mamantov

INTRODUCTION

In June 1983, I received an invitation to present a keynote address in the area of electrochemical power sources at the Sixth Australian Electrochemistry Conference. The first such conference was held in 1963; successive conferences have usually been held every four years. In addition to numerous speakers from Australia and New Zealand, a number of leading authorities from all over the world have been invited to present plenary lectures at these conferences. The plenary lectures of each Australian electrochemistry conference have been published in the form of a book; as a result these conferences have become widely known in the electrochemical community. Needless to say, I was anxious to participate in the Sixth Australian Electrochemistry Conference to be held at Deakin University, Geelong, Victoria, 19 - 24 February 1984.

- Aluminum Technology

I first met with the organizers of the Aluminum Technology course, Professor Barry Welch of the University of Auckland and his former student, Dr. Maria Skyllas-Kazacos of the University of New South Wales. Professor Welch is well-known for his studies in the area of aluminum smelting. Although the week-long course was being offered for the first time, there were numerous industrial participants from all over the world, including the United States, which also provided one of the lecturers, Dr. N. E. Richards, Reynolds Metals Company, Sheffield, Alabama. Another lecturer was Professor Kai Grjotheim of the University of Oslo, Norway, probably the leading authority on the chemistry of aluminum production.

- University of New South Wales

I next visited the University of New South Wales where I gave a lecture on "Chemistry and Electrochemistry in Molten Halides" and visited several faculty members at the School of Chemical Engineering and Industrial Chemistry, such as the head of the School, Professor David L. Trimm; Professor Christopher J. D. Fell who is known for this work on membrane processes and ultrafiltration; Senior Lecturer David J. Young who is working on high-temperature oxidation and corrosion; and my host Dr. Skyllas-Kazacos who is working in the area of the electrochemistry of molten salts and photo-electrochemistry. It is worth noting that all of the above faculty members have spent extensive periods of time lecturing and doing research abroad, including the United States. The ready availability of sabbaticals and other exchange programs for Australian scientists is an important factor in the high level of science "down under."

- Flinders University

The next visit on the agenda was to meet with Professor H. J. de Bruin, School of Physical Sciences, the Flinders University of South Australia. I had met Dr. de Bruin some twenty years ago at the Oak Ridge National Laboratory where he was a visiting scientist. Dr. de Bruin had organized a small workshop on applications of impedance spectroscopy to the metal/solid electrolyte interface; other workshop participants included Professor J. R. Macdonald, University of North Carolina, and Professor W. L. Worrell, University of Pennsylvania. I had a very interesting discussion with Dr. de Bruin on the Flinders Oxygen Probe, a device consisting of stabilized zirconia and two

palladium electrodes. This high-temperature device has been used by Dr. de Bruin and coworkers as a sensitive oxygen sensor [see for example, the paper by Badwal and de Bruin, J. Electrochem. Soc., *129*, 1921 (1982)]. One of the possible applications is the use of this probe in the Hall-Heroult electrolysis cell for the production of aluminum; such studies were conducted in de Bruin's laboratory.

- CSIRO Institute of Energy and Earth Resources

I was able to meet with Dr. E. J. Frazer, CSIRO Institute of Energy and Earth Resources, Division of Mineral Chemistry, Port Melbourne, Victoria. Dr. Frazer spent approximately a year in my laboratory after receiving his Ph.D. at the University of New South Wales. Although his doctoral and postdoctoral research involved electrochemistry in molten salts, Frazer is currently studying the fundamentals of zinc electrodeposition from acid zinc sulfate electrolytes. I also visited other CSIRO scientists, in particular Drs. T. Biegler, H. Gardner, and D. A. J. Rand.

- La Trobe University

I gave a lecture at the Department of Inorganic and Analytical Chemistry, La Trobe University. La Trobe is a relatively new university located in the suburbs of Melbourne. The head of the department, Professor R. J. Magee, has been involved in electroanalytical studies of transition metal complexes and organic systems; he is also interested in environmental chemistry. Dr. S. A. Tariq of that department is studying reactions in molten sulfates and carbonates.

SIXTH AUSTRALIAN ELECTROCHEMISTRY CONFERENCE

Deakin University, located on the outskirts of Geelong, is approximately one hour by car from Melbourne and was the location of the Sixth Australian Electrochemistry Conference. After the official welcome by the conference chairman, Professor A. M. Bond, Deakin University, the conference began with a very entertaining lecture, "Electrochemistry-The Interfacing Science," by Professor I. M. Ritchie, Murdoch University, Western Australia. The conference was organized into the following major topical areas:

- electrode surface studies,
- physical electrochemistry,
- electrometallurgy,
- semiconductor and photoelectrochemistry,
- teaching electrochemistry,
- trace electroanalysis (joint symposium with the Analytical Chemistry Division of the Royal Australian Chemical Institute),
- solid electrolyte cells,
- corrosion (joint symposium with the Australian Corrosion Association),
- organic and bioelectrochemistry,
- electrochemical power sources.

In addition, there was a plenary session to honor Professor Harry Bloom of the University of Tasmania who recently retired. Professor Bloom has published extensively in the area of electrochemistry of molten salts. My keynote address was presented in this plenary session. Other speakers in this session included Professor J. O. M. Bockris, of Texas A&M University, Professor Barry Welch, and Dr. Nolan Richards. Both Welch and Richards received their doctorates with Professor Bloom.

Over 80 papers and nearly 40 posters were presented during the five days of the conference. The titles of the major addresses along with names of the speakers are given below:

Author	Title
A. Bewick University of Southampton	IR Studies of Electrode Surfaces
A. T. Hubbard University of California, Santa Barbara	Electrochemical Processes at Well-defined Surfaces
R. P. Cooney University of Newcastle (Australia)	The Photochemical Origins of SERS Effects
T. J. O'Keefe University of Missouri-Rolla	A Review of Electrochemical Techniques Used for Evaluating Electrolytes
L. E. Lyons University of Queensland (lecture delivered by Dr. Graham Morris)	Semiconductors and Electrochemistry: Some Aspects of Cadmium Telluride and Solar Energy Conversion
B. Miller Bell Laboratories	Charge Transfer and Corrosion Processes at III-V Semiconductor/Electrolyte Interfaces
H. Bloom University of Tasmania	Electrochemistry-A Personal View of a Rapidly Developing Discipline
N. E. Richards Reynolds Metals Company	Developments in Aluminum Electrowinning
G. Mamantov University of Tennessee	Rechargeable High Voltage Low Temperature Molten Salt Cell Na/β"-alumina/SCl_3^+ in $AlCl_3$ - NaCl
J. O. M. Bockris Texas A&M University	Teaching Electrochemistry
R L. Paul Council for Mineral Technology, South Africa	The Role of Electrochemistry in the Extraction of Gold
J. C. Hamilton Footscray Institute of Technology, Australia	Achieving Full Potential in Undergraduate Electrochemistry
H. W. Nurnberg Nuclear Research Center Jülich, West Germany	The Voltammetric Approach in Trace Metal Chemistry of Natural Waters and Atmospheric Precipitates

T. M. Florence CSIRO Institute of Energy and Earth Resources, Australia	Recent Advances in Stripping Analysis
D. E. Smith Northwestern University	Fourier Transform Faradaic Admittance Measurements (FT-FAM): Background and Applications
D. C. Johnson Iowa State University	Electrocatalysis at Platinum Electrodes for Anodic Electroanalysis
W. L. Worrell University of Pennsylvania	A New Sulfur Dioxide Sensor Using a Novel Two-phase Solid Sulfate Electrolyte
J. R. Macdonald University of North Carolina	Analysis of Impedance Data for Single Crystal Na β''-Alumina at Low Temperatures
P. Zuman Clarkson College of Technology	Mutual Interactions Between Electrochemistry, Organic Chemistry and Biological Sciences
K. W. Hanck North Carolina State University	Electrochemical and Spectroscopic Studies of Transition Metal Complexes Having Multiple Successive One-electron Steps
D. H. Evans University of Wisconsin	Electron Transfer Reactions and Associated Conformational Changes. The Effect of Disproportionation on the Reduction of Bianthrone at Elevated Temperatures
K. Niki Yokohama National University	Electrochemical and Structural Studies of Tetraheme Proteins from Desulfovibrio--Standard Potentials of the Active Sites and Heme-Heme Interactions
K. M. Kadish University of Houston	Redox 'Tuning' of Metalloporphyrin Reactivity
R. Woods CSIRO Institute of Energy and Earth Resources	Advanced Batteries for Energy Storage
H. B. Mark, Jr. University of Cincinnati	Electrical Conducting Low Materials as Electrodes and Their Application in Electrocatalysis
J. McBreen Brookhaven National Laboratory	Rechargeable Zinc Batteries

The Bruno Breyer Medal was awarded to Professor A. J. Bard, University of Texas. Dr. Bard presented the Memorial Lecture, "Photoelectrochemistry and Solar Energy: Promise, Progress and Problems" before the formal conference dinner.

SUMMARY

In summary, the Sixth Australian Electrochemistry Conference was a very well organized meeting which resulted in an excellent overview of most currently important areas of electrochemistry, both fundamental and applied, and provided ample opportunities to meet colleagues from Australia and New Zealand. Such meetings frequently result in further scientific exchanges and collaboration.

In conclusion, I would like to acknowledge partial support for this scientific visit from the conference, the University of Tennessee and the Office of Naval Research, Far East.

FIFTH INTERNATIONAL CONFERENCE ON PHOTOCHEMICAL CONVERSION AND STORAGE OF SOLAR ENERGY

Kenneth M. Sancier

INTRODUCTION

The Fifth International Conference on Photochemical Conversion and Storage of Solar Energy was held in Osaka, Japan, at the Osaka Science and Technology Center between 26-31 August 1984. The chairman of the conference, H. Tsubomura of the Laboratory for Chemical Conversion of Solar Energy at Osaka University, is well-known for his fine work in photoelectrochemistry. The conference was attended by about 230 scientists from Japan and about 120 from other countries. The conference was supported by grants from the Commemorative Association for the Japan World Exposition and by many Japanese companies. Four previous international conferences were held: in 1976 at the University of Western Ontario (chairman, J. R. Bolton), in 1978 at Cambridge University (chairman, M. Archer), in 1980 at the University of Colorado (chairman, J. S. Connolly), and in 1982 at the Hebrew University (chairman, Dr. J. Rabani). The sixth international conference will be held in Paris in July 1986 and the chairman will be Dr. Jean Marie Lehn of Université Louis Pasteur.

An indication of the level of interest in photoelectrochemistry is the fact that two related postconference symposia were held. One was devoted to recent developments of photocatalysts and was held on 1 September at the Institute of Scientific and Industrial Research of Osaka University; the chairman was T. Kawai of Osaka University. The other was devoted to metal complexes of photochemical interest and was held 3 and 4 September at the Institute of Chemical and Physical Science, Wakoo-shi, and the co-chairmen were M. Imamura and A. Kira of that institute. Further evidence of interest in this general area of research was the 20th Okazaki conference which was held 17 to 20 August at the Institute of Molecular Science. This conference was devoted to powder and semiconductor electrochemistry and to artifical photosynthesis; about 40 invited scientists attended.

CONFERENCE STRUCTURE

The organization of the fifth international conference provided ample opportunity for information exchange among the participants. Eighteen plenary and invited lectures were given, and about 165 papers were presented in six poster sessions. Also, several panel discussions were held on the last half-day to review the accomplishments in the field since the preceeding conference in order to outline the most promising areas for further research. A special lecture was given by T. Horigome of the New Energy Development Organization (NEDO) on the status of solar energy development in Japan. Abstracts of the conference were provided, and the conference proceedings will be published in 1985. Last but not least, the organizing committee had given much thought in how to provide for the needs of the participants in a style for which the Japanese are unexcelled.

SCOPE OF PROGRAM

The amount of research in the field of photoelectrochemical solar energy conversion expanded dramatically 1972 after A. Fujishima and K. Honda of the University of Tokyo discovered that water could be decomposed into hydrogen and oxygen by irradiating a TiO_2 semiconductor electrode in aqueous solution that was connected electrically in the external circuit to a platinum electrode in the solution; hydrogen was evolved at the platinum and oxygen at the TiO_2 [*Nature, 238,* 37 (1972)].

Most of the conference papers were elaborations of this discovery. New materials and chemical systems were studied to improve the efficiency of converting solar energy into useful chemicals or electrical energy. Among the new materials were:

- different kinds of semiconductor materials,
- different metals which often were applied to the semiconductor surface,
- special polymer films which were applied to the semiconductor to decrease corrosion and to increase the separation efficiency of the photoproduced products,
- photosensitizer molecules which were added to the solution or applied to the surface of the electrode to increase the efficiency of light absorption, and
- redox couples affixed to organized molecular assemblies such as monolayers, miscelles, colloids, and polyelectrolytes.

Among the new chemical systems were artificial photosynthesis, organic synthesis to produce new compounds, and conversion of stereoisomers.

The main goal of most studies was to attain higher efficiencies for solar energy conversion and storage. The philosophy for attaining this objective was expressed in a lecture given by T. Matsuo of Kyushu University who suggested that the energy and conversion processes be conceptually divided into four steps:

- light absorption by the photosensitive system (e.g., semiconductor or metallo-organic compound),
- efficient charge separation at the photoreaction center,
- temporary storage of the photogenerated redox products, and
- conversion of the energy of redox processes into electrical energy or energy-rich stable and useful chemical products.

One or more of these steps were addressed in almost all of the conference papers. The diversity of the conference is reflected in the titles of the eight main topics of the poster sessions (the number of papers is in parentheses).

photoelectrochemistry at semiconductor electrodes (44)
heterogeneous photocatalytic reactions (38)
photogalvanic effects (8)
photovoltaic systems (9)
photoredox reactions and energy transfer in organized molecular systems (24)
photoredox reactions and energy transfer in homogeneous solutions (43)
mechanism and simulation of photosynthesis (12)
unimolecular energy storage reactions and other topics (11)

The six plenary lectures provided information on the status of photoelectrochemistry, including discussions of the theory, specific problem areas, and a review of new approaches. The speakers and the titles of their talks are listed below:

Author	Title
J. Rabani Hebrew University	Separation of photoredox products by local potential fields
Z. Yoshida Kyoto University	New molecular energy storage systems

T. Matsuo Kyushu University	Roles of organized molecular assemblies in artificial photosynthesis
S. Morrison Simon Fraser University	Problems and potential of the semiconductor/electrolyte approach to solar conversion
M. S. Wrighton Massachusetts Institute of Technology	Photoelectrochemical approaches to solar energy conversion
H. Tributsch Hahn-Meitner Institute	Interfacial processes involving strong electronic interaction in solar energy conversion and storage

STATUS OF PHOTOELECTROCHEMICAL SOLAR ENERGY CONVERSION AND STORAGE

Perhaps the best way to project the significance of a conference with such a diversity of papers is to consider the summary remarks that were made during the panel discussions which were held on the last day. Sir George Porter of the Royal Institute, the chairman of the session, expressed the belief that the photoelectrochemical approach to solar energy conversion has long-range potential and that there are many opportunities to develop new chemical processes to utilize solar energy, but that research has received limited support. He then posed three questions to the panelists and the audience, and the questions and the replies by the panelists to these questions are summarized below.

- What is the Most Significant Advance Since the Last Conference?

M. Grätzel of the Institute de Chimie Physique, Switzerland, thought that three areas were of greatest importance: photosynthesis, inhibition of photocorrosion of low-band gap materials (e.g., CdS), and various novel types of photochemical reactions (e.g., synthesis of amino acids and conversion of primary to secondary amines). In the case of water decomposition, significant advances had been made in developing new catalysts, but TiO_2 still appears to be the semiconductor material of major interest. Advances have also been made in developing sensitization procedures (e.g., anthracene, and his own work with ruthenium complexes). Advances in theory were made, for example, in selecting catalytic metals on the basis of d-band character.

M. Halmann of the Weizmann Institute cited the work on the fixation of CO_2 and N_2 as being of significance. In this connection, his own work was concerned with simultaneous photoreduction of carbonate ions and nitrogen on TiO_2 in alkaline aqueous carbonate. Also of note was the work of N. Kitamura, S. Kazama, and S. Tazuke of the Tokyo Institute of Technology on photochemical fixation of CO_2. Mention was also made of the work of K. Frese of SRI International, who was present at the conference, who had converted CO_2 to methanol with high efficiency of a GaAs photoelectrode.

A. Heller of the AT&T Bell Laboratories thought that the most important industrial benefit of photoelectrochemistry is the development of nonchalking paints. He also stated that the suitable challenges for further research and development are in converting bound nitrogen to ammonia and in the treatment of waste water to remove impurities.

T. Kawai of Osaka University remarked that advances had been made in mechanistic and kinetic studies and in developing better catalysts. He mentioned his own work on increasing the catalytic activity of Pt by distributing small crystallites on step-faces of a TiO_2 catalyst.

- Which Poster Session was Most Interesting?

M. Halmann made two selections: the work of A. Frank of the Solar Energy Research Institute and K. Honda of the Sagami Chemical Research Center on a dimeric ruthenium complex that can oxidize water, and the work of A. Heller of the AT&T Bell Laboratories on high loading of surfaces with very small crystallites of Pt that may provide ohmic contact with the semiconductor while still permitting 80% light transmission to the substrate.

A. Heller was impressed with the work of A. Fujishima, T. Kato, E. Maekawa, and K. Honda of the University of Tokyo on image formation that may lead to development of a new printing process. The imaging process depends on applying a very thin layer (e.g., monolayer) of stearic acid on TiO_2 that transforms the surface from hydrophilic to hydrophobic, and where light strikes the surface the stearic acid is photo-oxidized and the surface again becomes hydrophilic. Heller also cited the work on metal-sensitized photoisomerization reactions for storing and releasing solar energy; for example, the work of H. Sakuragi, T. Wakabayashi, T. Arai, and K. Tokumaru of Tsukuba University who worked with the isomerization of norbonadiene to quadricyclene.

- Which Research Areas are Most Likely to have Economic Consequences in Three to Five Years?

T. Kawai concluded that there are several areas of potential development including cleaning waste water with the generation of hydrogen, synthesis of new organic chemicals, development of slurry electrode systems, information storage, and photodeposition of metals on ceramic substrates to provide good electrical contact.

M. Grätzel suggested that cyanide ions might be removed by photo-oxidation during water treatment, and that nitrogen and sulfur oxides which cause acid rain might be removed from stack gases of power plants.

Sir George Porter suggested that the cost of new products and processes must be carefully examined. He concluded that the highest efficiency of solar energy conversion achieved so far is at a moderate level of less than 5%, and that energy storage had not yet been satisfactorily achieved.

J. R. Bolton of the University of Western Ontario, Canada, recommended further work be carried out on organized molecular assemblies which incorporate donor-acceptor systems into monolayers, miscelles, polyelectrolytes, and colloids. These systems may lead to advances in molecular electronics; for example, a p-n junction developed in a molecular photodiode. He further recommended that further work be done to obtain basic information on electron energy transfer processes.

T. Kawai suggested several possible applications should be pursued including: conversion of ethanol to acetaldehyde, water decomposition using larger metal particles in membrane systems, photosynthesis of assymmetric organic molecules, and development of hybrid semiconductor electrodes.

A. Heller recommended further work to prevent photocorrosion of III-V compounds, phototransfer of metals to substrates, and development of gas sensors.

CONCLUSIONS

Further research in the field of photoelectrochemistry will probably focus less on solar energy conversion and storage and more on certain promising areas that were identified during the conference. Some of the most promising areas include synthesis of special organic compounds, photoisomerization and conversion of stereoisomers, basic studies of the physics and chemistry of photoelectrodes surfaces of semiconductors, including catalysts of small metal particles and photosensitizers, macromolecular polymer systems that incorporate charge transfer materials/metal particles or means of separating the products of photochemical reactions, and artificial photosynthesis.

Some basic concepts of photoelectrochemistry may be ripe for application in the future. Some of the most promising areas include development of special semiconductor electrodes for gas sensors or other analytical measurements, energy transfer systems that may be useful in information storage devices, photodeposition of metals on the surfaces of semiconductors and ceramics, and photoetching or oxidation of coatings on the surfaces of semiconductors that may provide the basis of new imaging systems.

The prospects are poor that photoelectrochemical processes will be developed that are practical for converting and storing solar energy for power, such as the decomposition of water, because photovoltaic cells provide cheaper and more efficient alternatives.

A VISIT TO ICOT AND A NOTE ON THE 29TH NATIONAL MEETING OF THE JAPAN INFORMATION PROCESSING SOCIETY (JIS)

Raul Mendez

INTRODUCTION

On Tuesday, 11 September 1984, I visited the headquarters of the Fifth Generation Computer System Project, the Institute for New Generation Technology (ICOT). By coincidence, this date conflicted with the first day of the national meeting of the Japan Information Processing Society at Sendai, which I attended during the next two days. Some details on the Sendai conference are given below.

The ICOT visit began with a thirty-minute slide show, which is probably given to all visitors. After that, my host and I visited the research laboratory on the 21st floor of the high-rise Tokyo building where ICOT is located. Unfortunately, only a few of the researchers were present as most of them had gone to the meeting in Sendai. I saw about five PSI machines (PSI stands for Personal Sequential Inference; the greek letter "psi" is used frequently in ICOT conferences and proceedings). These machines were built by Mitsubishi Electric Corporation, and it appears that their successor is planned to be built by Nippon Electric Company (NEC), Matsushita Corporation, and Sharp Corporation. Presently there are about ten of the PSI machines at ICOT and there are plans to have twenty of them by 6 November, the starting date of the 1984 Fifth Generation Conference. (Since there are some forty researchers at ICOT, the PSI machines are not available yet on a one-to-one basis.) Subsequently, we visited the Relational Data Base Machine center (RDBM, usually referred to as DELTA) on the first basement floor of the building. This machine was built by Toshiba Ltd., and it serves multiple PSI machine users via a local area network. In an ICOT quote, "the relational model was chosen as a data base model for the data base machine because of its affinity to logic programming," (ICOT's *Technical Memorandum TM-04*).

Right now some of the researchers are busy preparing a demonstration program that will be presented at the Fifth Generation Conference in November. This conference is an important landmark in the development of this project. As the fifth generation project moves toward the end of its initial three-year phase, two of these years having elapsed, it approaches a period of transition which will probably will create many strains of its own. All of the present 40 "visiting researchers" must go back to their original companies some time next year, and the overlap time with the new crew will apparently be short.

My host, on leave from one of Fujitsu's research laboratories, emphasized throughout the tour that this was a project on basic research; that no readily marketable products will come out it; that the project seeks international cooperation on the development of the new generation of computers; that because of its unique approach the project must be viewed as an adventure whose successful outcome is by no means guaranteed; and finally that current research progress appears to be on schedule. On the other hand, Dr. K. Fuchi, one of the scientists who has contributed the most to the planning and actual implementation of the project, and who is now director of research at ICOT, views this project as one that will change the history of computer science. According to him, the project's basic idea is to return to predicate logic as the foundation for designing the next generation of computers:

...This could be interpreted as redesigning software and applications within that concept. Or it could be viewed as building new architecture machines as hardware to support the concept of logic programming...(Fuchi's key note speech at the 1983 FGCS Symposium).

Incidentally, a copy of this speech as well as a summary of ICOT's research progress up to about February 1984 is included in the most recent version of the ICOT *Journal Digest,* in English. I was given a copy of the *Digest* upon departing and was informed that copies of the technical memoranda referenced in it would be available upon written request. (Since this journal states only its year of publication, I am not certain of its publication date. The last ICOT technical memorandum (TM) listed in the reference section of the *Digest* is numbered *TM-0027* while one of the ICOT papers presented at Sendai refers to *TM-65*. The last memorandum referenced in the latest (March 1984) issue of the Japanese-language version of the ICOT *Journal Digest* is *TM-0040*. The *Digest* also includes a partial list of visiting researchers to ICOT as well as a list of ICOT researchers visiting international research organizations.

OUTLINE OF THE PSI MACHINE

The following summary is extracted from a paper (in Japanese) presented by one of the ICOT researchers, Akira Yamamoto, at the Sendai meeting:

> The PSI (Personal Sequential Inference) machine has been built to be used as a link in the R&D program of the Fifth Generation Computer System Project for an efficient environment for software development. This machine uses a PROLOG-like logical language called KL0 (Kernel Language Version 0) as its machine language. PSI directly interprets and executes KLO through an interpreter which is written in microcode (microinterpreter) via a special purpose part of the hardware.
>
> The programs to be executed by PSI (including the operating system, SIMPOS, Sequential Inference Programming and Operating System) must be written in KL0. To execute the operating system effectively, KLO includes a low-level hardware handling utility, with extended control and PROLOG-like functions. The clause expression written in KL0 is expanded by the compiler into a table of sequences of words consisting of clause head and body goals, the latter of which includes head argument and several goals; the microinterpreter interprets and processes this table at the same time.

Again, according to the most recent Japanese-language version of the ICOT *Journal Digest* the hardware of the PSI machine includes 40 bit x 16 M words of main memory, (according to my host, however, the actual memory of the machines we saw was 2 MB), 64 bit x 16 K words of control memory and 40 bit x 4 K x 2 of cache; TTL semiconductors are used in the CPU and 256 Kb NMOS chips are employed for the main memory. The machine runs at a clock cycle of 200 nsec and i , performance is apparently comparable to the 30 KLIPS(Kilo Logical Inferences) yielded by the DEC 2060 while running DEC10-PROLOG.

Additionally, input and output devices such as a bit-map display, a mouse and solid state disks are available in most PSI configurations. The present system, I am told, is still far from being completely debugged and it is still unclear how effective an environment it is for logic programming.

NOTE ON THE 29th NATIONAL MEETING OF THE JAPAN INFORMATION PROCESSING SOCIETY (JIS)

The Japan Information Processing Society meets twice each year, with one meeting held in Tokyo and another outside of the capital. The present meeting was held on the campus of the University of Tohoku in Sendai (400 km north of Tokyo) on 11, 12, and 13 September. There were 916 research papers presented at the conference; each was presented in a 15-minute session and was condensed in the proceedings into a two-page summary. As far as I could tell, the audience was almost entirely Japanese. As in most conferences, a two-page summary cannot contain all the information which is presented at each talk through overhead transparencies. In some of the talks I attended, the transparencies were written in English reflecting the general fluency of the Japanese speakers and audience in English.

Thirty of the contributed papers were originated in ICOT with nine on the PSI machine, ten on the operating system, SIMPOS, four on the relational data base machine (DELTA), three on knowledge acquisitions systems, two on concurrent PROLOG, one on the "Processes of writing in a nonnative language," and one on the "Study of a newspaper treatment of proper names." All of these except four were written in Japanese; the exceptions were the last two quoted above and two of the papers on the DELTA machine ("Unification in a knowledge base machine" and "Relational data base processing on an attribute-based scheme"). Additionally, there were a number of contributory research papers which were related to the fifth generation project but which did not originate with ICOT itself. For example, there were twelve papers on PROLOG presented by, among others, research scientists of companies such as Hitachi, Fujitsu, and NEC; and there were six papers on PIE (Parallel Inference Engine) presented by other scientists, mostly from Tokyo University.

On the topic of vector processors, there were thirteen papers; of these, eight were presented by the Fujitsu staff, two by NEC staff members, two by Kyoto University faculty and one by a professor from Tohoku University. These papers dealt almost exclusively with software for the vector processors. The two papers from Kyoto University gave a vector processor performance comparison between the Fujitsu VP-100 (at Kyoto University) and the Hitachi S810/20 (at Tokyo University). It is interesting to note that no papers were contributed by Hitachi on the vector processor session. As of this writing, it appears that Fujitsu is the only one of the three Japanese manufacturers engaged in supercomputer manufacture which is actively marketing in the U.S. This market effort is coordinated through Amdahl. In all, NEC presented 88 papers, Fujitsu Ltd., 80, Hitachi Ltd., 50, and IBM Japan, 47 papers.

There were ten papers on parallel architecture contributed by researchers from universities, and one presented by a scientist from NEC. The range of topics included papers on multiprocessors for specific application such as Gaussian elimination; most papers were concerned with arrays of microprocessors.

The number of papers presented and the topics discussed reflect the extraordinary intensity with which the Japanese are now pursuing their national goal of making the information and knowledge processing industry a vital, if not the most vital, part of their economy.

The references include the publications in English which have been referenced by some of the ICOT papers, as well as some of the papers on vector processors.

An appendix is included which summarizes the topics presented at the conference. In this appendix, next to each topic and affiliation, the number of papers presented is shown.

APPENDIX

SUBJECT	ORGANIZATIONS
Ability evaluation	University of Electrocommunications (six) Kyoto University (eight)
Applied data base	Hiroshima University (six)
Architecture	Mitsubishi Electric Corporation (ten) Toshiba Ltd. (eight) Nippon Electric Company (NEC) (seven) Tohoku University (nine)
Artificial intelligence	Toshiba Ltd. (10)
CAD system, etc.	University of Tsukuba (12)
Calculation	Nagoya University (nine) Chiba University (nine)
Center system	Osaka University (eight)
Character recognition	Electrotechnical Laboratory (ETL), Tsukuba (10)
Communication software	Tohoku University (13)
Compiler generation system	University of Tsukuba (13)
Data model	University of Library and Information Science (seven)
Data-driven machine	Musashino Electrical Communication Laboratory (ECL) (six)
Data base machine	Tokyo University (10) Hokkaido University (10)
Design support system	Electrotechnical Laboratory (ETL), Tsukuba (eight)
Display	Tokyo University (nine)
Document image processing	Toshiba Ltd. (six)
Education	Nippon Electric Company (NEC) (10)
Expert system	Science University of Tokyo (10)
Form processing	Nippon Electric Company (NEC) (11)
Form recognition	Kyoto University (eight)

Fundamental	Nagoya University (11) Tohoku University (10)
Hardware	Hiroshima University (nine)
Hardware description	Oki Electric Industry Company (six)
Image processing	Osaka University (nine) Nagoya University (10)
Image processing devices	Nippon Electric Company (NEC) (eight)
Inference machine	Keio University (nine) Institute for New Generation Technology (ICOT) (six)
Information retrieval	Kyushu University (nine) University of Library and Information Science (10)
Japanese language I/O	Tokyo University (nine)
Japanese processing system	Tokyo University of Agriculture and Technology (seven)
Japanese/kanji/kana conversion	Tokyo Institute of Technology (10)
Japanese/dictionary and word analysis	IBM Japan (10)
Japanese/sentence analysis	Fujitsu Laboratory (nine)
Japanese/translation	Kyoto University (six)
Knowledge acquiring	Fujitsu Laboratory (10)
Knowledge base	Osaka University (10)
Language comprehension	Hitachi Ltd. (nine)
Language for artificial intelligence (AI)	Tokyo Institute of Technology (nine)
Language processing system	Electrotechnical Laboratory (ETL) (six)
Large area network	Kokusai Denshin and Denwa Company (KDD) (six)
Layout	Waseda University (10) Mitsubishi Electric Corporation (13)
Local network	Nippon Electric Company (NEC) (seven)
Logic circuit design	Tohoku University (nine)
Logic simulation	Nippon Electric Company (NEC) (nine)

Machine translation	Tokyo Institute of Technology (12)
Microcomputer	Toshiba Ltd. (nine) Osaka University (eight)
NL processing	Kyushu University (nine) Toshiba Ltd. (nine)
Network appraisal	Osaka University (10)
Network management	Yokosuka Electrical Communications Laboratory (ECL) (10)
Network service system	Yokosuka ECL (six) University of Library and Information Science (seven)
Object-oriented language	Fujitsu Ltd. (10)
Office Systems	Mitsubishi Electric Corporation (nine) Fujitsu Ltd. (15) University of Tsukuba (six) Hitachi Ltd. (eight) Tokyo University (27) IBM Japan (eight)
PROLOG	Electrotechnical Laboratory (Tsukuba) (12)
PROLOG processing system	Tokyo University of Agriculture and Technology (seven)
Parallel processor	Seikei University (10)
Pattern processing	Yamanashi University (12)
Peripherals	Waseda University (13)
Programming language processing	Hitachi Ltd. (nine)
Programming tool	Yokosuka Electrical Communication Laboratory (ECL) (eight) Keio University (13) Toshiba Ltd. (10) Oki Electric Industry Company (nine)
Realization of system	Hitachi Ltd. (seven)
Realization techniques	Kobe University (six)
Robots	Osaka University (five)
Scattered data base	Yokosuka Electrical Communication Laboratory (ECL) (six)

Social systems	IBM Japan (10)
Software design	Mitsubishi Electric Corporation (eight) Hitachi Ltd. (nine) Kyoto University (10)
Software development and maintenance	Hitachi Ltd. (eight) Fujitsu Ltd. (10)
Software development environment	Mitsubishi Electric Corporation (nine) Fujitsu Ltd. (seven)
Software maintenance support	Fujitsu Laboratory (eight)
Software quality	Toshiba Ltd. (10)
Software reliability	Yokosuka Electrical Communication Laboratory (ECL) (10)
Statistic data base	Fujitsu Laboratory (10)
Vector processor	Hitachi Ltd. (13)
Verification	Tokyo University (10)
Voice recognition	Toshiba Ltd. (12)

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JAPAN SCIENCE AND TECHNOLOGY: AN OVERVIEW

Michael J. Koczak

A synopsis of Japan's efforts in government-funded research is provided with regard to the organization and scale of the effort, area of high government priority, role of government laboratories, objectives of the research programs and summary comments regarding the research strategy.

- Organization and Scale of Effort

The organizational and administrative structure of science and technology research expenditures according to the Prime Minister's office is detailed in Table I for private business, research institutes, and universities.

The distribution of funding over the ten year period from 1971-1981 has been maintained at about 60% private industry, about 25% for universities and 15% involving research institutes. Since 1975, the annual percent growth in science and technology research expenditures ranged from 10 to 15%. The research efforts in the United States have a scale of funding four times larger, but this includes larger defense, cultural and social science funding programs. Research funding is difficult to compare, i.e., for certain Ministry of International Trade and Industry (MITI) programs involving private industries and universities, the salaries are "donated" by the industrial institutions. If a comparison is made with U.S. government research expenditures, U.S. funding is cited as four times larger with 48.9% at industry and university laboratories, 22.7% for defense research, and 28.4% for others.

An agency summary of government research expenditures is provided in Table II, indicating the funding agencies as well as the percentage of effort. The funding efforts are subdivided in the following areas: 60% advanced development research, 25% applied research, and 15% basic reaearch. The Ministry of Education receives one-half of the funding with the Science and Technology Agency and the Ministry of International Trade and Industry receiving substantial fractions. Research expenditures are subdivided with 72.6% for industries and universities, 0.7% for defense, and 26.7% for other nondefense applications. Table III provides for the level of funding for the individual government ministries during 1981.

Several ministries have science and technology arms (Figure 1) in areas of engineering, health, energy, resources, etc. Specifically, under the Prime Minister's office are the Science Council of Japan, the Science and Technology Agency, Atomic Energy Commission as well as others. Under the direction of the Science and Technology Agencies, are the national laboratories, i.e., the National Aerospace Laboratory, National Research Institute for Metals, National Institute of Radiological Science, National Institute for Research in Inorganic Materials and the National Institute of Resources.

The Ministry of Education has direct supervision of the national universities, i.e., University of Tokyo, Kyoto University, etc., and their academic and research budgets. In the 1980 fiscal year, the total university, i.e., national, private, public, research budget was $3.43 billion @ $1 = 240 yen with $1.9 billion supplied by the Japanese Ministry of Education through the national university system, $1.33 billion by private universities and the balance in public universities. The expenditure can be subdivided by area of study with 13% going to science, 37% in engineering, 9% in agriculture, and 41% in health fields.

The Ministry for International Trade and Industry has under its jurisdiction the patent agency, the Agency of Natural Resources and Energy and the Agency of Industrial Science and Technology (AIST). The AIST promotes research and development programs in sixteen laboratories with a total budget in 1982 of \$494.0 million @ \$1 = 240 yen. These laboratories include the Mechanical Engineering Laboratory, Electrotechnical Laboratory, and several Government Industrial Research Institutes. Figure 2 provides for a further subdivision of the budget and personnel of AIST. Several completed large-scale programs are shown in Table V and ongoing programs in 1982 are provided in Table VI. A long-term program is the "Sunshine Project" designed to examine energy technology, excluding nuclear power. The four areas of concern involve solar energy, geothermal energy, coal gasification and liquefaction and hydrogen storage. The planned budget for 1982 for the "Sunshine Project" is detailed in Table VII with a total anticipated budget of \$1.73 billion @ \$1 = 240 yen. The second major program is the "Moonlight Project" which involves large-scale energy conversion technology. The major areas of interest include advanced gas turbines, waste heat utilization, magnetohydrodynamic power generation, advanced battery storage, fuel cell power generation technology, and Stirling engines. The project outlines coupled with FY 1982 budgets are detailed in Tabvle VIII.

The Ministry of Health and Welfare has ten institutes under its jurisdiction. Specific institutes address concerns of population, public health, mental health, nutrition, hospital administration, leprosy, cancer, and cardiovascular disease. The Ministries of Post and Telecommunications, Labor, Construction, Home Affairs and Finance have smaller research programs.

- Areas of High Government Priority

Japan's focused research program is directed in the areas of energy and knowledge-intensive industrial technologies. The energy effort in industrial and mineral technology is directed by MITI and has a 1983 energy budget allocated of 118.4 billion yen (\$493.0 million @ 240 yen = \$1). Areas of interest include secondary and tertiary oil recovery, oil shale and undersea oil development, heavy oil cracking and refining technology. In nuclear power, promotion of light water reactors, uranium recovery from sea water, nuclear safety and construction of an advanced thermal reactor. An energy related program, the "Sunshine Project," detailed earlier, linked to the development of solar, geothermal, hydrogen, and wind power will continue in 1983 to be funded at a level of 42 billion yen (\$175.0 million @\$1 = 240 yen). The energy conservation or "Moonlight Project" shall focus on five major areas: MHD power generation, advanced gas turbine, battery electric power storage, fuel cell power generation technology and an advanced Stirling engine and will receive 9.6 billion yen (\$40.0 million @\$1 = 240 yen) in 1983.

MITI's knowledge-intensive industrial funding shall receive 40.0 billion yen (\$166.0 million @\$1 = 240 yen). One such program, *R&D on Basic Technology for New Industries* includes twelve research themes in the areas of new materials, electronic devices, and biotechnology with funding of 5.8 billion yen (\$24.2 million) in 1983. The six program themes involved in the new materials area include: new ceramics, synthetic membranes for new separation technology, synthetic metals, high performance plastics, advanced alloys with controlled crystalline structures, and advanced composite materials. For electronic devices, three themes include superlattice devices for ultrahigh speed operations, three-dimensional integrated circuits, and fortified integrated circuits for extreme environmental conditions. The third area of biotechnology has three themes: bioreactors for micro-organism/enzyme production, large-scale cell cultivation, and recombinant DNA.

The second program is entitled *Large-scale National Research and Development Program*; themes include robotics in extreme conditions, laser assisted flexible manufacturing systems, manganese nodule mining and scientific computations funded at a level of 16.0 billion yen ($66.0 million @$1 = 240 yen).

The third program of research funding is comprised of *High Technology Industries* and has three major components:

- the information industry, i.e., R&D on the fifth generation computer, 2.7 billion yen ($11.0 million) and the next generation computer 2.9 billion yen ($12.0 million);

- aircraft industry, i.e., development of civil aircraft, 2.3 billion yen ($9.6 million) and an aircraft turbine engine for civilian use 4.7 billion yen ($20.0 million); and

- the nuclear power equipment industry with emphasis on control equipment and uranium enrichment, 1.7 billion yen ($7.0 million) and 0.2 billion yen ($0.8 million) respectively.

In addition to the MITI efforts, a government-supported semiautonomous organization has been established, the Japan Research and Development Corporation (JRDC) under the jurisdiction of the Science and Technology Agency. The program combines the efforts of academic, government, and industry research institutes. Six programs were funded during 1983.

THEME/COORDINATOR	BUDGET Yen (millions)	$U.S. (millions)
. Superfine particles C. Hayashi	497.0	2.07
. Special Structured Materials T. Masamoto	566.0	2.35
. Fine Polymers N. Ogata	312.0	1.30
. Perfect Crystals J. Nishizawa	500.0	2.08
. Bioholonics D. Mizuno	300.0	1.25
. Biological information O. Hayaishi	100.0	0.42

In these programs, a close relationship exists between the industry, government, and academic institutions promoting joint research for the private sector. The project is centered about an individual professor or industrialist who serve as project directors. Research teams are composed of young university or industrial scientists who are engaged in the research programs up to a maximum of a five-year period. The research project has less than thirty members who are grouped into subsets. For instance, the program on superfine powders is headed by Dr. Chikara Hayashi, President of ULVAC Corporation, a

materials and vacuum equipment manufacturing company. There are four subgroups in the program:

Basic Properties Group at Meijo University, Nagoya,
Physical Applications Group at Tsukuba, Ibaraki,
Biological/Chemical Applications at Maruzen Oil Company, Ltd., Saitama, and
Formation Process Group at ULVAC Corporation, Chiba.

An amorphous and intercalation compound study is headed by Professor T. Masumoto of Tohoku University with five groups involved in the special structured materials program. The blend of industrial, academic, and government research institutes is also seen by the mix of several cooperative groups:

Basic Properties Group	The Research Institute of Electric and Magnetic Alloys, Sendai, Miyagi
Amorphous Compounds Group	Otsuka Chemical Company, Ltd., Tokushima
Amorphous Thin Membrane Group	Gakushuin University, Tokyo
Special Ceramics Group	Furakawa Electric Company, Tokyo
Intercalations Compound Group	The Research Institute for Electric and Magnetic Alloys, Sendai, Miyagi.

- The Role of Government Laboratories

Government laboratories, i.e., the National Research Institute for Metals, Machine Engineering Research Institute, etc., participate in MITI and Science and Technology Agency funded programs. A coordinated and close linkage exists between the academic research programs (Ministry of Education sponsored) and materials efforts sponsored by MITI. In addition, some government laboratories perform "consulting" research programs in cooperation with industries.

- Objective of Research Themes

The goals of the research efforts are to sow the seeds and lay the groundwork for new developing technologies and industries. The MITI research effort promotes industrial technology to assure continued growth and expansion of Japan's economy, i.e., ceramics, the information industry, computers, aircraft, energy. Programs in basic technologies are creating the next generation of industries. In addition, research themes in energy, i.e., nuclear, oil, coal, high efficiency batteries, serve to reduce Japan's energy dependence. A government coordinated research policy selected current and future private sector industries for support and development. Themes in aircraft, satellite composite materials, high temperature alloys, serve as a springboard for the further development of the civilian and possible military airframe, satellite, and engine industry. In addition, it also serves to reduce Japan's energy dependence and improve the trade balance. From a trade export view, areas of research interest involve new materials, office automation, robotics, computers, biotechnology, and semiconductors. As a result, the MITI research effort is quite applied, coordinated and directed with more fundamental studies at universities and government research institutes.

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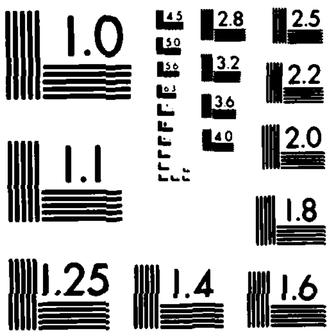

MICROCOPY RESOLUTION TEST CHART
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- Summary Comments on Research Strategy

Japan's research strategy can be easily viewed from an industrial and trade position. The country has few natural resources and must select or target areas of promise and sustain the efforts of strong industries. The areas of promise include information, aerospace, energy, biotechnology, electronics, and ceramics with funding directed to promote these efforts. For areas of current apparent strength which include electronics, robotics, the ferrous industry, ceramics, and machine tools, funding is helping sustain the growth or to slow the decline of these sectors. In certain sectors, i.e., the nonferrous/aluminum industry, a very energy-intensive area, primary production is declining and funding of this area may not appear productive. The funding directions have a clear and a close relationship to the economic well-being of the country.

A previous misconception concerning science and technology was that rather than investigating scientifically fascinating concepts, Japan's efforts were to accept a given body of knowledge, study it thoroughly, improve it and market a product. This generalization may have been appropriate in the past. At this point in time, Japan has taken a leadership position in significant areas and their development research efforts are in the forefront. They must now be quite careful in their basic research directions and degree of disclosure since the attendant financial risks are great. As a result, very hard scientific and economic decisions must be combined in order to assess the relative worth of research areas. The decision must be undertaken in a climate of fierce competition from industrialized as well as newly industrialized countries who are keen to accept new concepts and directions for new industrial products from acknowledged leaders. Japan is viewed as emerging into a second generation of scientific development where the growth and government cannot be sustained at the previous levels. New basic research directions must be selected with a swift allocation of resources with an associated smaller error margin. However, the greater level of scientific/industrial depth coupled with the large, educated and stable work force shall sustain and maintain Japan's competitive edge.

For further information, *Japan Science and Technology Outlook* from the Fuji Corporation is available. It is an English language book based upon white papers of the Science and Technology Agency. The chapters include: science and technology in Japan, development of original technology, research expenditure and personnel, collection and distribution of scientific information, technology transfer and patent applications, international cooperation, allocation for government research, government promotion of research, government assistance for private research, strengthening the foundations of research and toward more creative science and technology.

Japan Science and Technology Outlook, published by the Fuji Corporation:

Busicen Building
Jingu-mae, Shibuya-ku
Tokyo 150, Japan

Telephone: 03-409-6291
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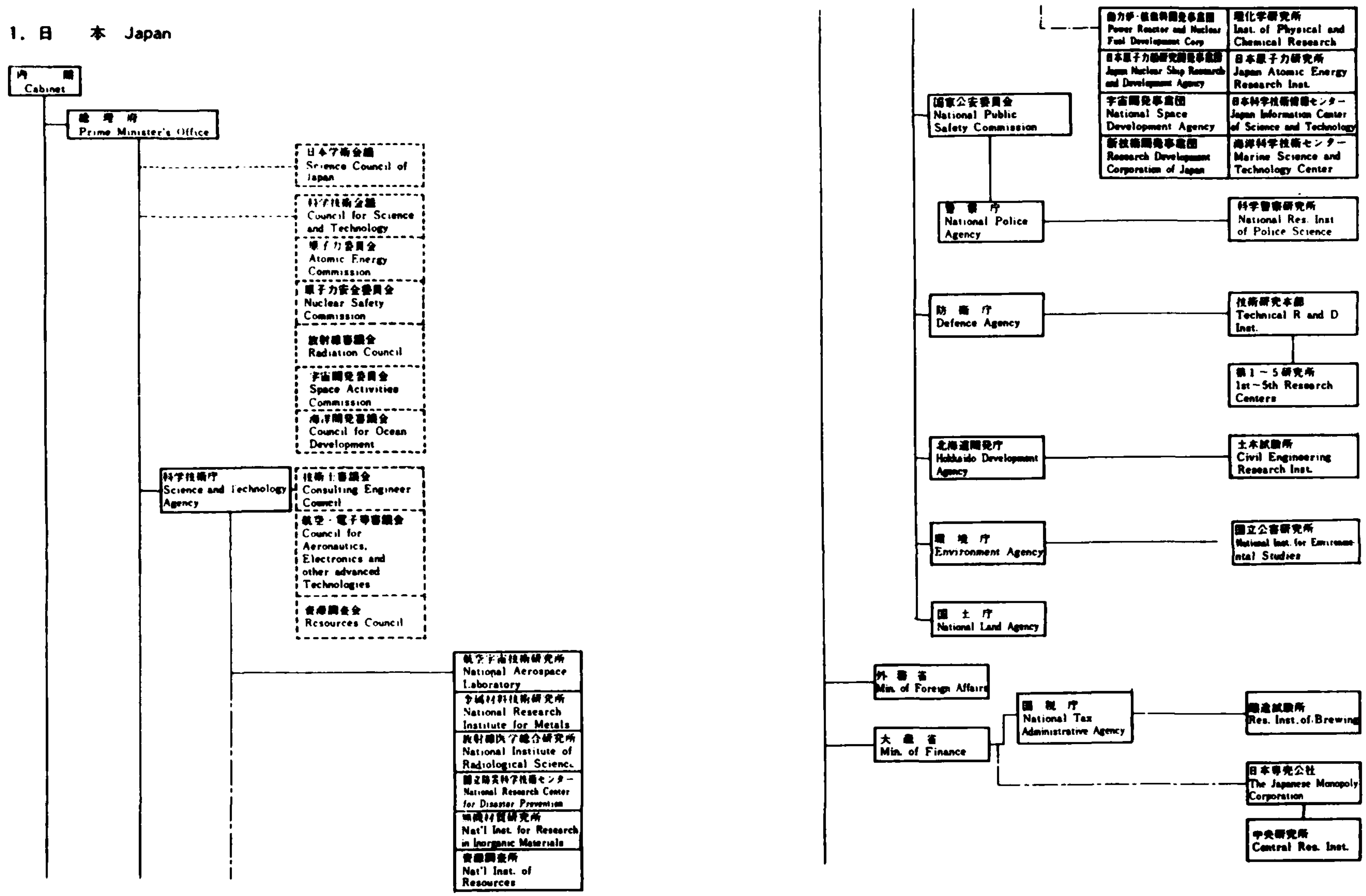


Figure 1. Administrative Organization of Science and Technology in Japan. (*Indicators of Science and Technology*, published by the Science and Technology Agency, Tokyo, Japan, 1982).

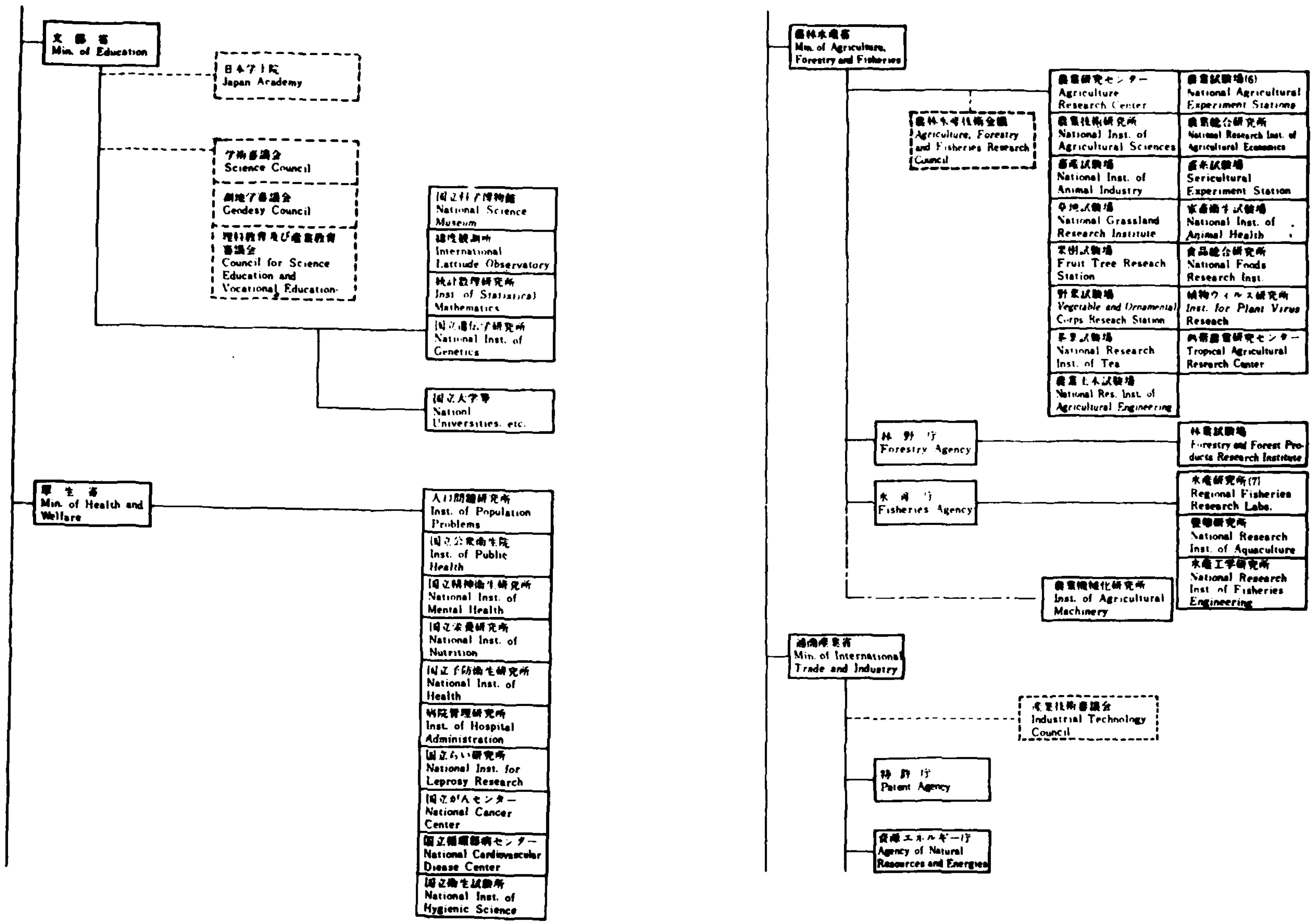


Figure 1. Administrative Organization of Science and Technology in Japan (continued).

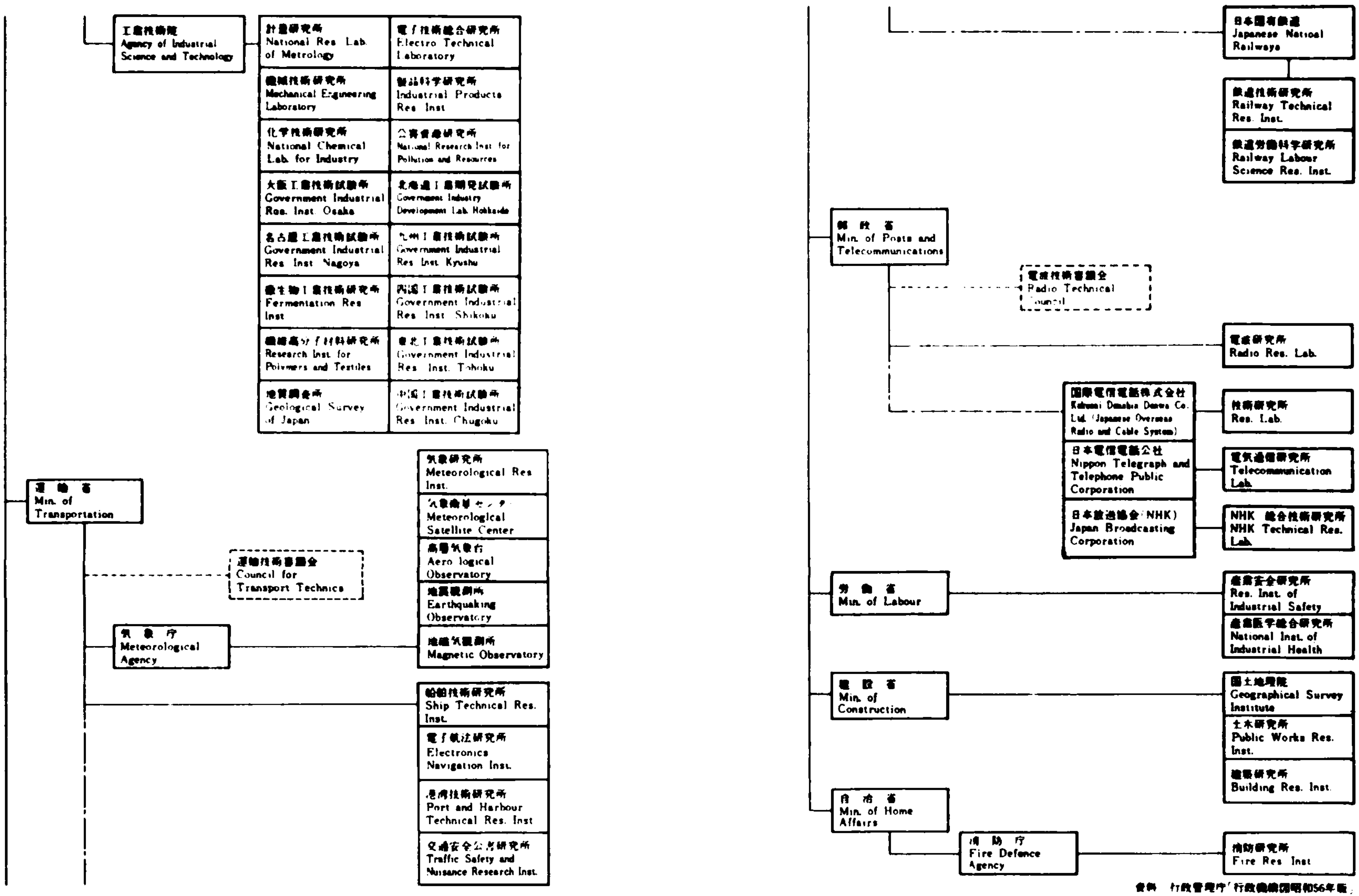
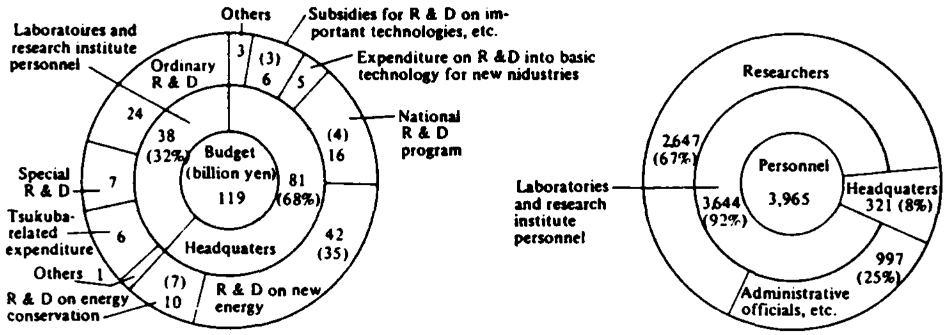


Figure 1. Administrative Organization of Science and Technology in Japan (continued).

FY1982 BUDGET AND PERSONNEL

• **Budget and Personnel of AIST**

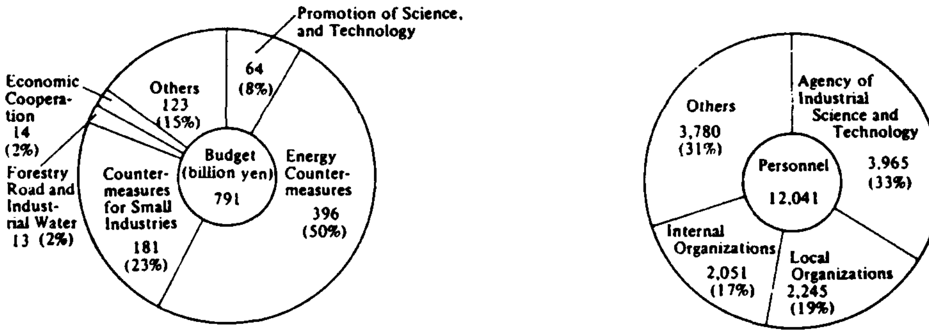


Note 1: Budget: Expenditure for Science and Technology promotion, Budget for Energy Countermeasures, Special Budget, Others
Ordinary R & D: Expenditure for AIST, Research Laboratories.
Special R & D: Expenditure for; Special Research, Expansoin of Laboratory Facilities, Operation of Geological Research Vessel, Nuclear Research, Countermeasures for Small Industries, Research Related to Prevention of Environmental Pollution.
Others (Research Laboratories): Expenditure for; Promotion of Special Researches, Execution of Commissioned Work, Foreign Patent Applications, Current Research, Regional Technology Development, International Industrial Technology Reserach, Seminar for Small Industries, and Expansion of Facilities.
Subsidies for R & D on Important Technologies: Subsidies for Development of Important Technologies, Development of Medical and Welfare Equipment Technologies.

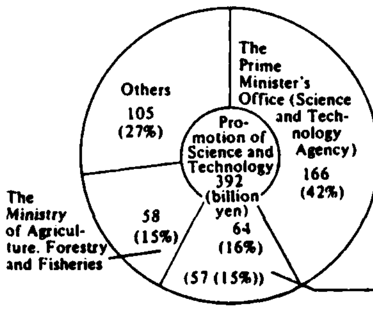
Note2: Figures indicated in parentheses are special budgets.

Note 3: Special R & D Budget includes 3.0 billion yen transferred to other sections.

• **Budget (Ordinary Budget) & Personnel of MITI**



• **National Budget for Science and Technology Promotion**



• **Personnel of National Research Organizations**

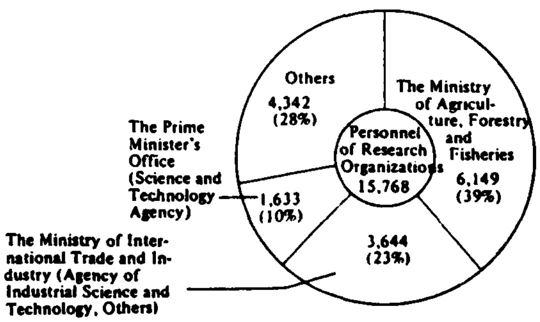


Figure 2. Budget and personnel for AIST and MITI *(Handbook of the Agency of Science and Technology)*.

TABLE I

	Private Business	Government Research Institutes	Universities (etc.)	Total
1971 (yen, billions)	895.0	213.9	423.4	1,532.3
1971 ($ U.S., billions) (230 yen = 1$)	3.73	0.89	1.76	6.38
1981 (yen, billions)	3,629.8	906.9	1,445.6	5,981.5
1981 ($ U.S., billions) (230 yen = 1$)	15.12	3.77	6.02	24.91

TABLE II

Government-funded Research

Ministry of Education, Science and Culture	50%
Science and Technology Agency	27%
Ministry of International Trade and Industry	13%
Ministry of Agriculture, Forestry and Fisheries	4%
Defense Agency	4%
Others (Transportation, Construction, Communications, etc.)	2%

TABLE III

JAPAN RESEARCH ESTABLISHMENT

Ministry of Education, Science and Culture	$ 2,870*
Science and Technology Agency	$ 1,510*
Ministry of International Trade and Industry	$ 760*
Ministry of Agricultural, Forestry and Fisheries	$ 250*
Defense Agency	$ 140*
Ministry of Health and Welfare	$ 110*
Ministry of Transportation	$ 50*
Environment Agency	$ 50*
Ministry of Construction	$ 30*
Ministry of Post and Telecommunications	$ 20*
Ministry of Foreign Affairs	$ 20*
Government Total	$ 5.6**
Industry Total	$ 16.8**
Total Budget (FY81 @ $1 = Y240)	$ 22.4**

* Millions of yen
** Billions of yen

15% Basic Research
25% Applied Research
60% Advanced Development

TABLE IV

SCIENTIFIC AND TECHNOLOGICAL RESEARCH EXPENDITURES

(In Billions of Yen)

	Total	Private Business	Research Institutions	Universities, etc.
1971	1,532.4	895.0	213.9	423.4
	(100)	(58.4)	(14.0)	(27.6)
1978	4,045.9	2,291.0	603.8	1,151.1
	(100)	(56.6)	(14.9)	(28.5)
1981	5,982.4	3,629.8	906.9	1,445.6
	(100)	(60.7)	(15.2)	(24.2)

Note: Percentage share in parentheses.
Source: Prime Minister's Office.

TABLE V

COMPLETED NATIONAL RESEARCH AND DEVELOPMENT PROJECTS
(Source: *Handbook of Agency of Science and Technology*)

Completed National Research and Development Projects (Large-scale Projects)

(Unit: million yen)

Project name	*Period (FY)*	*Total expenditure*	*Outline of project*
Super-high performance electronic computer	*1966 – 1971*	*about 10,000*	*Large scale computer system with super-high performance*
Desulfurization process	*1966 – 1971*	*about 2,600*	*(1) Efficient removal of the SO_2 contained in the grass exhausted from power plants or other industries which consume a great deal of heavy oil.* *(2) Direct removal of sulfur from heavy oil.*
New method of producing olefin	*1967 – 1972*	*about 1,100*	*Economic production of olefins by direct cracking of crude oil instead of using naphtha.*
Remotely controlled undersea oil drilling rig	*1970 – 1975*	*about 4,500*	*Remote-control oil drilling rigs for undersea use.*
Sea water desalination and by-product recovery	*1969 – 1977*	*about 6,700*	*Economical large-scale production of fresh water and economical by-product recovery technology*
Electric car	*1971 – 1977*	*about 5,700*	*Various types of electric car to replace ordinary vehicles in urban areas.*
Comprehensive automobile control technology	*1973 – 1979*	*about 7,300*	*Integrated control technology with a view to relieving traffic congestion, reducing automobile pollution and traffic accidents, etc.*
Pattern information processing system	*1971 – 1980*	*about 22,000*	*Computer technology for the recognition and processing of pattern information such as characters, pictures, objects and speech.*
Direct steelmaking process using high temperature reducing gas	*1973 – 1980*	*about 13,700*	*Direct steelmaking technology with a view to solving the pollution problems that accompany present-day methods and reducing the dependence on coal as a raw material. The new technology aims at a closed system which uses the heat energy from a multi-purpose high temperature gas-cooled reactor in the steelmaking process; this new reactor is scheduled for development in the near future.*
Olefin production from heavy oil as raw material	*1975 – 1981*	*about 13,800*	*Technology for manufacturing high-value-added olefin (commonly known as ethylene, propylene, etc.) using a high sulphur-content heavy oil fraction (so-called asphalt), which is difficult to desulphurize, as the raw material.*
Jet engines for aircraft	*1976 – 1981 (3nd phase)*	*about 13,000*	*Research and development of large scale turbofan engine designed for the use in commercial transports in the 1980s.*
	1971 – 1975 (1st phase)	*about 6,900*	

TABLE VI

ONGOING NATIONAL RESEARCH AND DEVELOPMENT PROJECT
(Source: *Handbook of Agency of Science and Technology*)

Ongoing National Research and Development Project *Unit: million yen*

Project Name	R & D Period (FY)	Total R & D Expenditure	Budget for FY1982	Outline of Project	Main R & D Activities in FY 1982
Resource Recovery Technology	1976 – 1982 (2nd phase) 1973 – 1975 (1st phase)	about 11,300 1st phase: about 1,300	733	R & D on technical systems for the disposal of solid urban waste, centered on resource recycling with a view to promoting the efficient utilization of resources and facilitating the smooth application of solid urban waste treatment.	Comprehensive research on the operation of energy recycling type facilities and materials recycling type facilities.
Flexible Manufacturing System Complex Provided with Laser	1977 – 1983	about 13,000	3,311	R & D on complex production system in which mechanical components for small batch production of diversified products can be flexibly and rapidly produced from metallic materials in an integrated system.	Fabrication of Manufacturing System Complex Test Plant
Optical Measurement and Control System	1979 – 1987	about 18,000	3,237	R & D on measurement control system that uses optics and makes possible the systematic measurement, integrated observation and control of mass information, including visual information arising in specific areas, such as industrial parks, large-scale plants, etc., even under adverse conditions such as those where electromagnetic induction etc., prevails.	System: detailed design of functional subsystems for various functions: research on essential technology for the fabrication of opto-electronic IC (OEIC).
C (Monocarbon) Chemical Technology	1980 –	about 15,000	2,527	R & D on technology for the stable and economic production of such basic chemical products as ethylene glycol, acetic and ethanol etc., with C_1 compounds such as carbon monoxide obtained from alternative carbon sources such as natural gas coal, tarsand, etc., as their basic raw materials.	Comprehensive R & D on the performance of catalyst and the preparation of membrane.
Manganese Nodule Mining System	1981 – 1989	about 20,000	882	R & D on efficient and reliable mining systems using hydraulic pump and/or air lift pump for deep-sea deposits of manganese nodules which contain economically important metals (Ni, Cu, Co, Mn, etc.)	Basic design of the total system and subsystems such as collector, material lifting, machinery handling, electrical control & data assembling, and fundamental experiment on vertical slurry transportation.
Scientific Computing System	1981 – 1989	about 23,000	813	R & D on high-speed computer system for processing and computation of scientific and technological information (processing of image information from satellites, simulation of nuclear fusion, etc.) which present computers cannot handle in realistic time.	R & D on high speed logic and memory devices such as Josephson, Junction GaAs EET and so on. And research on high speed parallel processing systems.
Automated Sewing System	1982 –	–	–	R & D on automated sewing system that is composed of several processes such as preparation, making-up and finishing, for the apparel industry faced at diversification and rapid change of domestic demand.	Planning of the R & D program for the entire project and conceptual designing of essential technologies for automatic cloth spreading, cutting, making-up, etc.
Subsea Oil Production System	1978 – 1984	about 15,000	3,515	R & D on subsea oil production system (in which production from small-scale oil fields is possible without any adverse effects on the fishing industry) which is effective for subsea oil production in deep waters (over 300m deep) and suitable for use in the sea areas surrounding Japan.	Test manufacture of some of the equipment for comprehensive marine experiments: final design and production work on other experimental equipment. Detailed planning for experiments.

TABLE VII

BUDGET AND PROJECTS FOR THE SUNSHINE PROJECT
(Source: *Handbook of Agency of Science and Technology***)**

Planned FY 1982 Budget for "Sunshine Project" *(Unit: 100 million yen)*

Projects	FY 1974	FY 1975	FY 1976	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982	Work plan in FY 1982
1. Solar Energy	8.7	10.9	14.2	14.6	20.1	37.7	95.4	79.6	87.1	1. Operation for examination of 2 types (plane-parabola type, central receiver type) of solar thermal power generation pilot plant. 2. Studies on new type solar cells and a low cost production process of solar panels 3. Construction of photovoltaic generation pilot systems 4. Construction of solar industrial process heating systems
2. Geothermal Energy	5.6	11.4	15.5	25.6	31.8	35.5	80.1	92.2	94.9	1. Technology for exploration and extraction of geothermal energy 2. Technology for 10,000 kW class binary cycle geothermal power generation test plant and total flow pilot test plant utilizing hot water 3. Technology for hot dry rock power generation system 4. Technology for deep geothermal water supply systems 5. Technology for multi-purpose utilization of geothermal energy and environmental preservation 6. The demonstration program for environmental protection on development of large scale power plant using deep geothermal reservoir
3. Coal Gasification and Liquefaction	4.4	8.6	9.1	10.1	14.4	29.0	85.5	135.1	206.4	1. Operation of 40 t/d low-calorific gasification plant 2. Operation of high-calorific gasification plant with a capacity of 7,000 m^3/d 3. Operation of 1 t/d solvolysis liquefaction plant 4. Operation of 1 t/d solvent extractive liquefaction plant 5. Operation of 2.4 t/d direct liquefaction plant
4. Hydrogen Energy	3.3	4.6	4.5	5.2	5.9	6.9	9.5	9.5	9.2	1. Construction and operation of high-temperature high-pressure water electrolysis pilot plant (20 m^3/hr) 2. Studies on storage and transportation of hydrogen by metal hydrides 3. Studies on utilization of hydrogen (Combustion etc.) 4. Studies on safety of hydrogen (Prevention of explosion etc.)
5. Original and Supporting Research	2.0	2.5	3.0	2.8	3.1	3.5	5.5	12.3	10.7	1. Supporting research and management Total energy system, Management of R & D, Information service 2. Exploitation of seeds technologies Ocean thermal energy conversion, Wind energy conversion, Biomass (Biomimetic conversion of solar energy)
6. International Cooperation	–	–	0.2	0.2	0.3	0.5	6.8	6.7	6.7	1. Cooperaion on dry rock project of IEA 2. IEA Contribution
7. Others	0.5	1.6	2.7	3.4	5.6	6.3	3.6	1.1	1.3	Office expenses
8. Total Budget	24.4	39.6	49.2	61.8	81.3	119.4	286.5	336.6	416.4	

TABLE VIII

BUDGET AND PROJECTS FOR ENERGY CONSERVATION TECHNOLOGY
(Source: *Handbook of Agency of Science and Technology*)

R & D on Large-scale Energy Conservation Technology *Unit: Million yen*

Project Name	R & D Period (FY)	Total R & D Expenditure	Budget for FY1982	Outline of Project	Main R & D Activities in FY 1982
Advanced gas turbine	1978 – 1984	about 21,000	6,035	Development of a gas turbine that will raise thermal efficiency to a remarkable 55%-plus in a combined generating cycle with a steam turbine; R & D on ultra-high temperature resistant materials and component technology will enable the temperature at the turbine inlet to be raised to 1,500°C, etc.	A pilot plant (generation efficiency 50 percent) of the 100,000kW class will be manufactured and prepared for test run.
Waste heat utilization technology systems	1976 – 1981	about 4,000	95	R & D on elementary technologies and total systems for the utilization of waste heat, including heat recovery, heat exchange, heat transmission, heat storage, etc. with a view to conserving resources and energy in industry and promoting the effective utilization of waste heat by the community.	R & D was completed in 1981 and the results are being arranged.
Magneto-hydro-dynamic power generation	1976 – 1982 (2nd phase) 1966 – 1975 (1st phase)	about 10,684 1st phase: 6,450 2nd phase: about 4,234	592	R & D on MHD electric power generation technology to improve performance and durability of the power generating channel at the 15 MW thermal input ETL Mark VII MHD test facility, and also to solve some basic problems in coal-fired MHD power generation using program-pulverized coal mixture fuel for 0.3 MW thermal input and COM fuel for 1.5 MW input, respectively, at ETL test facilities.	Construction of the Mark VII test facility (using ordinary magnets) has been completed and experimental runs of 200 hours at 100 kW were successfully conducted.
Advanced battery energy storage system	1980 – 1990	about 17,000	858	The development of highly efficient batteries to store electrochemically surplus power at off-peak time and release it at peak.	Studies will be conducted into basic technology for new-type 1 kW class batteries (Na/S, Zn/Cl_2, Zn/Br_2, Redox flow), systems analysis of electrical networks using simulation mechanisms, and total systems for battery storage of energy.
Fuel cell power generation technology	1981 – 1986	about 11,000	618	R & D on highly-efficient fuel cell power generation system for electric utility application, which are able to use various fuels (natural gas, methanol, coal gas, etc.), applicable to dispersed siting of small-size plants and/or concentrated siting of large-size plants. The types of fuel cells to be developed are phosphoric acid fuel cells for 1,000 kW system, molten carbonate fuel cells for 10 kW output, solid oxide fuel cells for 1 kW output, and alkaline fuel cells for 5 kW output.	On the phosphoric acie electrolyte fuel cell, manufacturing technology of the large size fuel cells with high efficiency, fuel cells stacking and fuel processing technologies are being researched and developed. On the other types of the fuel cells, advanced material and cell composing technologies are being conducted.
Stirling engines for wide use	1982 – 1987	about 10,000	275	R & D on Stirling engine for wide application aim at high thermal efficiency (32 to 37%), low-noise and pollutant emission and high durability with advanced components, system designing and manufacturing/operating technologies. 3 kW and 30 kW heat pump driving and 30 kW electric generator driving a Stirling engines will be developed.	In the first fiscal year 1982, simulation analyses of engine performance, conceptual design of the base-line Stirling engines best suited to the each application, the development of component technologies, are to be conducted.

INTERNATIONAL SYMPOSIUM ON CHRONOBIOLOGY

P. F. Iampietro

INTRODUCTION

Interest in biological rhythms is not of recent origin. However, during the last two decades a greater interest has been generated, primarily because of an increased awareness of the importance of rhythms in almost all aspects of our lives. Research has been directed to examination of the centers controlling rhythms and the mediators associated with that control. The role of biological rhythms in determining tolerances to shift work is receiving a great deal of attention. Medication and toxicant effects and effectiveness are significantly modified by the time of day administered and the clinical applications of this are being explored. Factors which alter or modify biological rhythms is an extremely important aspect of those situations in which shifts in rhythms are required as an adjunct to adaptation to the environment. All of these examples, and the list is not inclusive, indicate the importance of this area of research. Consequently, it has been found necessary to provide a forum in the general area of chronobiology where researchers who do not usually talk to each other would have a means for exchange of information.

The International Symposium on Chronobiology held in Ootsuka (Kyoto), Japan from 31 July-2 August 1984, brought together a small, multidisciplinary group (about 30) of researchers from Japan, United States, Australia, and West Germany (one invited individual from France could not attend) to discuss their most recent work.

The content of the symposium was quite varied and some papers did not appear to be particularly suitable to this meeting. For example, in one session of four papers, three of the four were concerned with environmental physiology with little or no relation to chronobiology. However, the material presented did provide an excellent foundation for other papers more directly concerned with environment and rhythms. The organizer does not plan to publish a proceedings so the papers presented at the symposium will be discussed in some detail here.

SCIENTIFIC SESSIONS

After introductory remarks by the organizer of the meeting, Dr. T. Morimoto of Kyoto Prefectural University of Medicine, Dr. Hisato Yoshimura, one of the most respected and internationally-known Japanese physiologists, presented the welcoming address and provided the historical basis for the development of the current meeting.

The symposium was divided into two main sessions and each of these was further divided into subsessions.

- Session I. An Attribute of Adaptability to Natural Environments

The role of the pineal gland in the control of biorhythms in mammals was described by R. J. Reiter of the University of Texas Health Science Center, San Antonio. This presentation provided a good foundation for the other papers in the meeting. The pineal gland is thought to be a prime regulator of rhythms through the production of melitonin which is mediated by dark and suppressed by light. Light, through the eye, affects the suprachiasmatic nucleus of the hypothalamus and through a spiral pathway to the pineal gland. Rhythms are setup in the pineal gland in the production of melitonin with the

highest production being during night time. Melitonin is released into the blood stream and it is metabolized primarily in the liver and excreted in the urine. If light is of sufficient intensity, all rhythms in the pineal gland can be suppressed in all mammals which have been studied. A number of drugs can also alter pineal rhythms--either inhibiting or stimulating melitonin production. These drugs are primarily β-receptor agonists or antagonists. The physiological functions of the organisms affected by these changes in pineal rhythmicity have yet to be defined. However, a connection has been proposed between sexual activity and pineal rhythms. Darkness suppresses sexual activity in some hibernating mammals which may be a protective mechanism since young born in winter would probably not survive. The mechanism is not known. Additionally, temperature regulation, insulin activity, jet lag phenomena and others may be related to pineal activity.

Human circadian rhythms are governed by a multioscillator system. R. Wever of the Max-Planck-Institut für Psychiatrie in West Germany has studied the effects of varying (lengthening or shortening) sleep-wake cycles, or the intensity of illumination on separation of rhythms of different variables. In general, different rhythms are not entrained at the same rate. So some rhythms may break off fairly readily when day-night cycles are varied while other rhythms may be very resistant. This would mean that these rhythms probably do not have functional interconnections or they would oscillate in synchrony.

H. Tokura of Nara Women's University, Japan, discussed light and temperature on locomotion. Ambient temperature had no consistent effect on entrainment but changes in light-dark cycles caused disruption in locomotion patterns. Circadian periods showed a positive correlation with light intensity. The author believes that there may be a coupling between light-dark cycles and temperature cycles thereby having additional effects on biorhythms.

Endogenous rhythms of rat pups, blinded at one day after birth can be entrained by a nursing mother during the nursing period regardless of whether the mother is the natural mother or a foster mother. However, K. Takahashi of Shiga University in Ootsu, Japan, found that if the pups were transferred to a foster mother after ten days of age the rhythm (drinking) was never entrained by the foster mother. Entrainment occurred if the transfer took place before four days of age had passed.

Fiber growth (fleece) in sheep and goats is a circannual rhythm. Day length is the controller of fleece growth in photosensitive animals. B. McDonald, Queensland Animal Research Institute, Australia, treated sheep with continuous light and changed the period of fleece growth to six months. The author speculates that the photoperiods in cashmere goats does not affect fiber shedding and growth cycles so these rhythms may be endogenously controlled, perhaps mediated through the pineal gland.

Desert mammals according to M. Yousef, University of Nevada, develops various strategies in order to cope with their harsh environment. Lack of water and food, high temperatures (low desert), and low temperatures (high desert) are some of the factors posing problems to survival. Some desert mammals allow body temperature to vary when food is in short supply. Hibernating animals (in cold rooms) increase their daily periods of hibernation in order to budget their food requirements. Some animals sleep to have reduced heat production during activity in the desert, thereby reducing evaporative water loss and food requirements.

Comparison of natural acclimatization of desert (Negev Desert in Israel) residents with acclimatized subjects from North America was the subject discussed by E. Nadel of the Pierce Laboratory and Yale University. Body temperatures after work were lower than for North American residents, but forearm blood flow and sweating rate were the same as for unacclimatized subjects. Heat rate during work was also lower. The author speculates that the desert residents were able to maintain plasma value at a higher level than unacclimatized subjects by enhanced venodilation. There was thus an improved cardiovascular function in the desert residents.

K. Shiraki (University of Occupational and Environmental Health, Japan) and S. K. Hong (University of Buffalo) described renal function of men exposed to high ambient pressure during multiday diving exposures. In most saturation dives, a nocturnal diuresis occurs without an increase in fluid intake and without a net loss in body water. The extra urine output appears to be balanced against a decreased insensible water loss. The diuresis occurred even when body temperature (skin) was maintained at normal level (i.e., diuresis was not cold-induced). Aldosterone and ADH are not major factors in the diuresis and not due to changes in renal hemodynamics. There was a reduction in negative free-water clearance, however.

A study of basal metabolic rate in indigenous and nonindigenous populations (Japanese and foreign) showed that indigenous populations had a higher metabolic rate. Metabolism in indigenous groups in northern or southern (high latitudes) areas had higher metabolic rates than those living near the equator. Nonindigenous groups in the same areas showed only a small increase in metabolism (T. Sasaki, Kumamoto University, Japan).

S. Yamaoka (Saitama Medical School, Japan) studied sleep rhythms in guinea pigs, rats and rabbits as a function of steroid-central nervous system interactions. He concluded that estrous cycle-dependent changes in sleeps rhythms were present in rats and guinea pigs. An ovariectomy changed rhythms in rats and rabbits, and estrogen restored the changes in rats and guinea pigs. Progesterone enhanced the estrogen effects in rabbits. The central feedback site might be in the forebrain limbic structures in the rat and rabbit and in the medial preoptic area in the guinea pig.

According to W. Engelmann (Institut für Biologie, West Germany) lithium chloride shifts the entrainment of locomotor rhythm in the hamster to longer periods. Sensitivity to a light pulse is decreased when the salt is given. Possibly the effect of lithium is mediated by its effect on membrane function.

- Session II. Chronobiology-Application to Clinical Medicine, Occupational Hygiene and Safety

An interesting study of tolerance to shift work and circadian rhythms was done by G. Hildebrandt (Universität Marbourg, West Germany). He concluded that subjects with later circadian phase position (so-called evening types) are less impaired by night and shift work than subjects with an earlier phase position (morning types).

The effects of shift work and age on a target aiming function test and critical flicker fusion were studied in factory workers. In general, older workers scored better than young workers. Performance among the three shifts was not different (K. Sakagami, Matsushita Science Center, Japan).

Intolerance to shift work is hypothesized to correlate with inability to maintain the circadian rhythm of body temperature equal to 24 hours. A. Reinberg (Fondation A. de Rothschild, France) presented evidence wnich showed that shift workers who were intolerant of shift work as exhibited by clinical symptoms (persistent fatigue, changes in mood and behavior, sleep disturbances, digestive troubles, etc.) also showed a body temperature with a period deviating from 24 hours or free-running. An interesting aspect of this work is that the author showed that a shift worker may function perfectly well for many years with no discernible clinical symptoms and with a stable body temperature and then he may become intolerant of shift work with symptoms and a free-running temperature. An adequate explanation for this finding was not given.

Traffic accidents in Texas were examined for possible temporal patterns. The author (P. Langlois, University of Texas at San Antonio) found strong weekly and circadian rhythms and there were peaks on weekends.

Recently, the relationship between biological rhythms and the effects of drugs, toxicants, nutrients, etc., has received a great deal of attention. An important aspect of drug therapy is the dose/effectiveness relationship. Time of day, and therefore the phase of biorhythms, have been found to show differences in the disposition of theophylline in children, for example. This may be due primarily to differences in the rate of absorption from the gastrointestinal tract. M. Smolensky (University of Texas at Houston) presented information on the pharmacodynamics of theophylline and indicated that the drug has different effects (effectiveness) on target organs as a function of biological cycles. Plasma levels and mortality also vary with time of day.

Y. Chiba (Yamaguchi University, Japan) presented an interesting study of school-refusers (children who refuse to attend school) and biological rhythms, primarily rest-activity cycles. The author believes that two kinds of circadian rhythms control rest-activity cycles and maintain a synchronization such that in healthy conditions the cycle is 24 hours. The synchronization is broken in the refusers and one of the oscillators is more in control so the cycle is free-running with a period longer than 24 hours.

The last paper of the symposium was concerned with the circadian rhythm of circulating blood volume in the rat. T. Morimoto (Kyoto Prefectural University of Medicine, Japan) described a methodology developed in his laboratory for continuously measuring circulating blood volume in rats. The method requires a splenectomy and catheters in the aorta and jugular veins. A tracer (51 Cr-tagged red blood cells) was injected and the blood was continously read in a well-type gamma ray detector. Blood volume data were not given.

SUMMARY

This symposium can serve as a springboard for future meetings in this important area of research. Chronobiology, especially its application to shift work, medicine, rapid time zone transit, etc., is realizing increased attention. Future meetings should be more well-defined as to content and therefore will be of more value to the participants. More attention should also be paid to the mechanisms of regulation of biological rhythms. As an indication of the importance of the study of rhythms, a new journal, *Chronobiology International*, has been launched to provide a vehicle for this type of research.

SYMPOSIUM ON WAVE BREAKING, TURBULENT MIXING, AND RADIO PROBING OF THE OCEAN SURFACE

Ming-Yang Su

INTRODUCTION

The Symposium on Wave Breaking, Turbulent Mixing, and Radio Probing of the Ocean Surface was held at Tohoku University, Sendai, Japan, 19-25 July 1984. This symposium was organized by Tohoku University as one of the joint activities of the IOC/SCOR Committee for Climate Changes and the Oceans (CCCO) and the WMO/ICSU Joint Scientific Committee for the World Climate Research Program (JSC) with Professor Y. Toba, Tohoku University, as chairman for the organizing committee, and Professor H. Mitsuyasu, Kyushu University, as chairman of the advisory committee which was comprised of 16 internationally-known authorities on various aspects of the symposium. This symposium is a sequel to the Inter-Union Commission on Radiometeorology (IUCRM) Symposium on Wave Dynamics and Radio Probing of the Ocean Surface, 13-20 May 1981, Miami Beach, Florida. A total of 84 papers with 71 papers in oral sessions and 13 papers in poster sessions was presented, which included four special invited papers. About 200 scientists attended the symposium, which was comprised of about 140 Japanese and about 60 delegates from 16 other countries. The symposium was opened by Professor Toba, and two keynote addresses were given. The first address was given by Dr. Nakau Ishida, President of Tohoku University, and was followed by Professor John D. Woods, of CCCO/JSC. Dr. Ishida expressed his welcome to the international meeting and the importance and timeliness of such a meeting. Professor Woods gave an overview of the World Climate Research Program and World Climate Observations (1988-1998).

The scientific program was divided into 13 consecutive sessions (the number of papers for each is given in parentheses):

- nonlinear wave dynamics (five)
- wave generation (six)
- wave dynamics, wave statistics and wave modeling (seven)
- wave models (six)
- wave-current interaction and radio probing (five)
- drift current, wave breaking and turbulence (seven)
- wave dynamics and microwave probing (seven)
- radar, SAR, scatterometry (six)
- scatterometry and altimetry case studies (five)
- remote sensor development (four)
- upper ocean mixed layer (three)
- turbulence and Langmuir cells in the upper ocean (four)
- mixed layer model and climate (six)
- two poster sessions (13)

A book of extended abstracts of the accepted papers was distributed at the time of registration. The proceedings of the symposium containing the presented papers, after standard referee's reviews, shall be edited jointly by Professors Toba and Mitsuyasu and published in the near future. The above list of session titles should give a strong indication of the broad subjects on near ocean surface phenomena which were discussed. The thirteen oral sessions and two poster sessions were obviously divided, mainly for the convenience of conducting one session in either the morning or the afternoon; one major subject might be covered in more than one session while one session might cover several more restricted subjects.

In this report, we shall briefly describe some highlights of scientific findings presented at this symposium with emphasis placed more on wave dynamics than on radio probing aspects which, unavoidably, reflects the author's personal interests and familiarity with the subject selected rather than the relative significance of the selected subjects.

This symposium was meticulously organized and carried out by the local organizing committee at Tohoku University as clearly evidenced by the distribution to all participants of an extraordinary amount of prepared materials which covered every need, particularly for foreign participants.

SCIENTIFIC SESSIONS

- Nonlinear Wave Dynamics

The first paper of the symposium was given by Professor W. H. Hui and Dr. G. Tenti of the University of Waterloo, Canada, who discussed a new, powerful formulation for nonlinear water theory in which the pressure is regarded as an independent variable and the continuity equation replaced by two stream functions. This new approach resulted in the free surface boundary conditions becoming linear, and the governing equations becoming amendable to symbolic computation by a computer. P. A. F. M. Janssen, Royal Netherlands Meteorological Institute, [Koninklijk Nederlands Meteorologisch Institut (KNMI)] presented computations for the longtime behavior of a random, inhomogeneous field of weakly nonlinear surface gravity waves. His main finding is that the wave instability is quenched by a spectrum broadening. M. Stiassnie, Technion, (Israel Institute of Technology) Israel, and L. Shemer, of the Massachusetts Institute of Technology (MIT), discussed the initial instability and longtime evolution of Stokes waves based on their recently modified version of the Zakharov integral equation for surface gravity waves, which includes both Class I and Class II nonlinear interactions. Their most important finding is that a kind of Fermi-Pasta-Ulam recurrence phenomenon occurs for both classes. M. Y. Su and A. W. Green, Naval Ocean Research and Development Activity, (NORDA) U.S.A., presented experimental results showing the evidence of strong coupling between Class I and Class II instabilities for deep water surface gravity waves of moderate steepness. This finding provides a physical mechanism for the frequently observed wave breaking and directional energy spreading in growing seas. H. C. Yuen, TRW Space and Technology Group, U.S.A., examined the order and chaos of the longtime evolution of a weak nonlinear wave train using a spectral formulation of the nonlinear Schrodinger equation. His most surprising result, among others, is that the inclusion of more spectral components, each with its own individual frequency, simplifies rather than complicates the evolutionary process (contrary to normal expectations).

- Wave Generation

K. V. Gastel, P. A. E. M. Janssen, and G. J. Komen, KNMI, presented computations on the generation and growth of gravity-capillary waves by wind and wind-induced shear current. They find that the phase velocity is mainly sensitive to the current profile and the growth rate to the wind profile, and that the growth rate of the initial wavelength scales with the third power of the friction velocity. Y. L. Yuan, N. E. Huang, and C. C. Tung, of the Institute of Oceanology, Academia Sinica, People's Republic of China, theoretically examined four aspects of nonlinear waves in a developing process:

- three time scales of the dispersion relationship,
- the derivation of a generalized nonlinear Schrodinger equation with comparison to a third-order Strokes equation, and
- the analytical solution of the nonlinear single wave and its instability.

Most of the theoretical computation agrees with the laboratory experiments. Professor M. T. Landahl, MIT, and Royal Institute of Technology, Sweden, discussed nonlinear effects of short waves on the transfer of wind momentum to long water waves using a third-order wave interaction formulation. His computation shows that the modulation of the short-wave Reynolds stresses by the long-wave may produce a phase shift in the long-wave pressure so as to increase the momentum transfer to the long waves. Dr. Hasselman, University of Hamburg, and M. Dunchkel and J. Bosenberg, Max-Planck-Institut für Meteorologie, Federal Republic of Germany (FRG), presented some simultaneous measurements of atmospheric pressure and surface gravity waves at a fixed meteorological mast in the North Sea. These data are used to test the conjecture, with good agreement, that nondimensional pressure-induced growth rate can be parameterized by the ratio of the friction velocity to the phase velocity. P. A. E. M. Janssen and G. J. Komen, KNMI described their study on the effect of atmospheric stability on the growth of surface gravity waves by numerically solving the Taylor-Goldstein equation for wind profiles which deviates from a logarithmic one. They find that atmospheric instability has significant influence on wave growth, and proposed an improved parametrization of the wave growth rate including the effect of stability. H. Kawamura and Professor Y. Toba, Tohoku University, Japan, presented experimental findings on several new aspects of turbulent boundary layers over wind waves. These include the somewhat ordered motions in air flow having a horizontal length scale corresponding to wavelengths of the underlying wind waves; two distinct air flow patterns with and without separation; and the bursting phenomenon near the wind waves which are shown to produce a major part of the Reynolds stress.

- Wave Dynamics, Wave Statistics and Fundamentals of Wave Modeling

In an invited paper, Professor M. S. Longuet-Higgins, from the University of Cambridge, United Kingdom, described a new way to calculate the surface profile and the flow in steep, progressive gravity waves based on a system of quadratic relations for the coefficients in Stoke's expansion which he derived earlier. He gave, analytically, conditions for the bifurcation of a uniform wave train into steady, nonuniform wave trains with precise agreement with those found by Chen and Saffman [*J. Fluid Mechanics* (1980)] using an integral equation. He further proved several new integral relations for gravity waves, among them the Eulerian-mean angular momentum is proportional to the Lagrangian density with both being stationary in the case of the phase speed having a maximum or minimum. R. E. Glazman, University of Rhode Island, U.S.A., proposed the generalization of phenomological approach, which was initiated by Professor M. S. Longuet-Higgins, to evaluate the flux density for energy lost by wave breaking by using spectral moments of vertical acceleration of surface displacement rather than the displacement itself. N. E. Huang, National Aeronautics and Space Administration (NASA), Goddard Space Flight Center, presented derivations of statistics of nonlinear random waves: one for the probability density function for surface elevation, and another for the non-Gaussian joint probability density function of slope and elevation. Various conditional and marginal density functions are also obtained through the joint density function. The theoretical computations were found to agree well with the laboratory experiments also conducted by the author and his co-workers. P. C. Liu, Great Lakes Environmental Research Laboratory, National Oceanic and Atmospheric Administration (NOAA), discussed his attempt to search for universal parametric correlations for wind waves using data collected in the Great Lakes. Essentially, he found that there are little seasonal effects and indistinguishable atmospheric stability effects. G. J. Komen (KNMI), Dr. K. Hasselman and S. Hasselman, Max-Planck-Institut für Meteorologie, FRG, discussed the energy transfer equation for well-developed ocean waves under the influence of wind, and the conditions for the existence of an equilibrium solution in which wind input, wave-wave

interaction and dissipation balance each other. Among many trials, one of their solutions which approaches equilibrium is close to the Pierson-Moskowitz spectrum with a particular angular distribution. D. E. Irvine, the Johns Hopkins University, discussed the modulation of short wave spectra due to a long wave both in the absence and the presence of wind. He found that in the former case, the modulation of frequency spectra is dominated by the variation of both frequency and action flux, while the modulation of wave number spectra is dominated by the variation in wave number. K. K. Puri and B. Pearce, University of Maine, described some computed effects of surface contamination on the drift velocity of water waves.

- Wave Models

In this session, three related papers were presented on a detailed intercomparison of three prediction models for shallow water waves by the SWIM group which comprises the following three institutions:

- British Meteorological Office, with the BMO model,
- Royal Netherlands Meteorological Institute, with the GONO model, and
- Institut für Meereskunde and Max-Planck-Institut für Meteorologie, FRG, with the HYPA model.

This comparsion covered three parts:

- different concepts to model shallow water waves,
- results for ideal wind and depth situations, and
- hindcasting a storm event in the North Sea.

The results of these intercomparisons of the three models are mixed in their merits and deficiencies and cannot be summarized in the present short report. The fourth wind wave prediction model for waters of arbitrary depth using energy flux arguments, and in terms of the JONSWAP parameter set, was described by H. C. Graber and O. S. Madsen, MIT. This model was used to hindcast wave conditions in coastal waters for the ARSLOE storm. The overall agreement of predictions and observations are considered excellent. P. A. E. M. Janssen, KNMI, and W. J. P. de Boogt, Delft Hydraulics Laboratory, Netherlands, reported on their investigation of the effect of bottom friction on the evolution of wind sea under a constant wind by integrating the transport equation for the energy density. Their main finding with support from field measurements is that the saturation level of the wave energy is rather insensitive to variations in the bottom dissipation coefficients.

- Wave-Current Interaction and Radio Probing

O. M. Phillips of the Johns Hopkins University, discussed in an invited paper, two main aspects of spectral and statistical characteristics of breaking waves. First, in the equilibrium range of wind-generated waves, he derived the frequency spectrum of the -4 power law in consistence with the empirically form found earlier by Professor Toba and others. This leads to other power law estimations of spectral rates of energy loss and momentum loss by wave breaking. Second, he obtained the statistical distribution of breaking fronts which strongly depend on the phase speed and the friction velocity. D. T. Chen and G. R. Valenzuela, Naval Research Laboratory (NRL), and S. A. Piacsek, NORDA, described the experimental observation of the interaction between steady, nonuniform two-dimensional currents and two-dimensional spectra of ocean waves at the NRL Remote Sensing Experiment at Nantucket Shoals, Maryland. They also described the approach of numerical modeling, based on the kinematic and energy balance equations by the method of

characteristics for simulating the wave-current interaction problem. The numerical computation was not completed at the time of the symposium. R. L. Rai *et al.*, David W. Taylor Naval Ship R&D Center, presented the results of the measurement and analysis of surface waves in a strong current as part of the same NRL experiment. Another field measurement and analysis of wave-current interaction phenomenon was reported by F. I. Gonzalez, Pacific Marine Environmental Laboratory, NOAA, who made both the SLAR and *in situ*, wave/current measurements at the Columbia River entrance, and showed some interesting results. W. Alpers, Max-Planck-Institut für Meteorologie, FRG, presented a weak hydrodynamic interaction theory which describes the modulation of the short Bragg scattering wave by the variable current associated with tidal flow over bathymetry and with internal waves.

- Drift Current, Wave Breaking, and Turbulence

H. Mitsuyasu and T. Kusaba, Kyushu University, Japan, described their experimental findings of wind-generated turbulence in the water by comparing the spectra of velocity components for clear water and for the water containing a surfactant. Their measurements suggest that the turbulent structure in the water surface boundary layer generated by the wind action has many of the features similar to those over a solid surface. E. A. Terray, Woods Hole Oceanographic Institution, presented an analysis of turbulence below breaking waves in the laboratory and field based on a method of linear filtration to distinguish waves from turbulence, and found that the turbulence spectra show a single Kolmogoroff inertia subrange for frequencies near the wave spectral peak. J. Wang, National Taiwan University, and J. Wu, University of Delaware, reported water turbulent measurements in a circulating tank under both longitudinally bounded and unbounded conditions. Besides the further confirmation of the -5/3 power law of the turbulence spectra, they found distinct differences in the depth dependence of the Reynolds stress between the above two conditions. H. Tsuruya, S. Nakano, Port and Harbor Research Institute, and H. Kato, Ibaraki University, Japan, described the experimental results of wind drift current measurements in a wind-wave tank, with and without return flow, and found that the drift current with return flow is about 15% higher than the other case. W. K. Melville, R. J. Rapp, and E. S. Chan, MIT, reported observations and analysis of laboratory experiments on unstable breaking wave trains and programmed individual breaking events. Their measurements showed close correlations between the incidents of breaking with the wave group structure, but poor correlations with wave height alone, and that a variation of breaking wave patterns occurs as a function of initial wave steepness. L. H. Holthuijsen and T. H. C. Herbers, Delft University of Technology, Netherlands, discussed some statistics of breaking ocean waves measured by a waverider buoy and concurrent direct visual observations in the North Sea. Their results on joint distributions of wave heights and periods and other statistical parameters failed to give the expected distinction between the breaking and nonbreaking waves which reflects the current confusion on proper ways to identify "breaking waves" in a random sea. They also found good correlation between the occurrence of wave breaking and wave groups. S. J. Hogan, University of Cambridge, presented the analytical computation of particle trajectories of nonlinear capilliary waves up to and including the highest wave. The orbits of the steeper waves are found to be neither circular nor closed, and the influence of increased surface tension is to increase the horizontal distance traveled by a particle as well as the magnitude of the drift current.

- Wave Dynamics and Microwave Probing

G. R. Valenzuela, Naval Research Laboratory, U.S.A., gave a comprehensive, invited review on the pertinent physical processes in microwave scattering from the ocean surface,

and their applications to radar probing of ocean waves/currents with single and multifrequency systems including radar imagery such as SAR and SLAR. The physical processes included Bragg scattering, specular scattering, and contributions from wave-breaking. P. Forget, Université de Toulon Et Du Var, France, described the measurement of the wind wave field in fetch-limited conditions by using two ground wave high frequency radar systems operating simultaneously at two frequencies, fe and 2fe, from which directional spectral properties of the wave field and the steepness of individual waves were estimated. A. Shibata *et al.*, Meteorological Research Institute and Radio Research Laboratories, Japan, reported some measurements of the Doppler spectra of the C-band radar echo returned from both calm and rough sea states. A. Takeda, M. Takuda, and I. Watabe, National Research Center for Disaster Prevention, Japan, described the measurement of directional sea wave spectra using a two-frequency microwave scatterometer under strong wind conditions. Though the power spectral peak of the cross product of the radio returns was found to correspond well with the resonance waves, their system still encountered several problems to be solved prior to routine operational utilization. D. E. Weissman, Hofstra University, and J. W. Johnson, NASA Langley Research Center, reported the measurement of the directional ocean wave spectra of large gravity waves by using an airborne two-frequency scatterometer at Ku-band. The modulation transfer function was inferred from the wave measurements by the surface contour radar and the XERB pitch and roll buoy. An important result of this experiment (ARSLOE) was the demonstration of the directional capability of the two-frequency scatterometer. M. S. Banner and E. H. Fooks, University of New South Wales, Australia, discussed their measurements of microwave reflectivity properties of small-scale breaking waves which are induced by a stationary hydrofoil against an opposing current in the laboratory tank. They concluded that the microwave reflectivity under such conditions is consistent with Bragg scattering from the disturbances due to breaking waves. D. S. W. Kwah and B. M. Blake, TRW Space and Technology Group, U.S.A., reported a very impressive study of the relative contribution of Bragg and non-Bragg scattering mechanisms to the total microwave backscattering from water waves for a range of radar and surface parameters in a laboratory wind-wave tank. For mechanically-generated waves without wind forcing, they found that both wedge diffraction and specular reflection are important in addition to Bragg scattering. For wind-generated waves at high winds, Bragg scattering and Rayleigh scattering produces two distinct spectral peaks in microwave returns.

- Radar, SAR, Scatterometry

N. Iwata of the Tokyo University of Mercantile Marine, proposed an algorithm for calculating backscatter cross sections of microwaves from a perturbed sea surface for the range of incident angles between 30° and 70° based on several assumptions of the wind wave properties. This model yields close comparison with the SASS model for high wind speed. W. J. Plant, W. C. Keller, Naval Research Laboratory, and D. E. Weissman, Hofstra University, reported the X-band microwave backscatter measurement from a tower in the Gulf of Mexico. Their measurements are found to depend on wind-speed, air-sea temperature differences, and the total root-mean-square slope of the large gravity waves that modulate the short capillary waves. One implication of these data analyses is that two or more quantities should be measured simultaneously in order to acquire the most accurate air-sea parameter information. F. Feindt *et al.*, Max-Planck-Institute für Meteorologie, FRG, presented some first results of C-band radar cross section measurements obtained from circle flights over the North Sea. The experimental data show that C-band frequency is a suitable frequency band for measuring surface winds over the ocean. D. B. Trizna, Naval Research Laboratory, discussed the experimental results of simultaneous, dual-polarized X-band radar scatter from ocean waves progressing from deep

water to shoaling and finally to breaking at the shoreline. Changes in the polarization ratio of the radar returns were observed as a function of range, as waves begin to exhibit crest-like features and breaks. H. Masuko *et al.*, Radio Research Laboratories and National Space Development Agency of Japan, described the experimental results of sea-surface scattering measurements by an airborne microwave scatterometry radiometer operated at X-band and Ka-band. These measurements indicated that the capillary wave spectrum is anisotropically similar to the gravity-capillary spectrum. Y. Karasawa, T. Shiokawa, and M. Yamada, of the Kokusai Denshin Denwa Company, developed a model and made measurements for multipath fading of L-band circularly polarized waves, which is caused by the interaction between the reflected waves from the sea surface and direct incident waves from the satellite. The model predicted a fading spectra with good agreement with field measurements.

- Scatterometry and Altimetry Case Studies

Y. Sugimori, A. Tsubomatsu, and M. Ogihara, Tokai University, Japan, reported the computations of the volume scattering function of the microwave scatterometer for different empirical formula for directional dispersion, and for cases with and without wave-current interactions and wave-wave interactions. The computation, in particular, shows the importance of wave-current interaction which causes rapid deformation of wave patterns and energy exchange. J. R. Apel, D. G. Tilley, and P. Van Dyke, the Johns Hopkins University, provided an estimation of amplitude (near 80 meters) of internal solitary waves in the Andaman Sea using satellite imagery by regarding these surface signatures in terms of damped conoidal waves. This estimate compares favorably with in-water data by other investigators. A. G. Kjelaas, Stolt-Nielsen Seaway Submersibles AS, and J. Guddal, Norwegian Meteorological Institute, Norway, discussed an application of SEASAT remote sensing data and wave model predictions on sea-state features of severe Atlantic storms. Their experiment confirmed the expectation that the model prediction and satellite data are compatible. R. Coleman, University of Sydney, Australia, showed another application of SEASAT and GEOS-3 radar altimeter data for studying the spatial distribution of mesoscale sea variability in the Tasman Sea; the satellite data generally agree with existing hydrographic measurements. K. Sato, M. Ooe, International Latitude Observatory of Mizusawa, and T. Teramoto, University of Tokyo, Japan, provided yet another example of application of the SEASAT altimeter data for estimating sea surface height and ocean tides in the northwest Pacific Ocean. They also discussed some uncertainties of the current ocean tide models, and the possible improvement of the current ocean tide models by using the satellite data.

- Remote Sensor Development

Four remote sensors and associated software processing systems were reported in this session. Their titles and authors are simply listed here with no further comments:

Title	Author (s)
- MIROS- A microwave remote sensor for the ocean surface.	O. Gronlie, D. Brodtkorb and J. Woien, Norway
- The design of spaceborne microwave scatterometer.	H. Yamada *et al.*, Japan
- On-board processing of microwave altimeter-numerical simulation and real time simulation using BBM.	Y. Miyachi *et al.*, Japan

- Simulation of wind-vector estimation-design evaluation of microwave scatterometer. — M. Shimada and M. Sasanuma, Japan

- Upper Ocean Mixed Layer

S. A. Kitaigorodskii, the Johns Hopkins University, gave an invited lecture on the influence of breaking waves on the dynamics of the upper ocean with special emphasis on the contribution of breaking waves to gas transfer across the air-sea interface, and a general theory of wave-turbulence interactions. J. S. Harindra Fermando, California Institute of Technology (CIT) and R. R. Long, the Johns Hopkins University, presented some laboratory experiments with comparison to some earlier theory of fundamental aspects of spreading of mixed regions in two-layer and linearly stratified fluids in the absence of mean shear. A. Masuda, Kyushu University, discussed experimental results of entrainment in two- and three-layer stratified fluids both in inertial and in rotating systems where turbulence for mixing is produced by an oscillating grid. It is found that the rotation causes the downward entrainment.

- Turbulence and Langmuir Cells in the Upper Ocean

I. S. F. Jones, University of Sydney, reviewed some field measurements of horizontal velocity fluctuation in the upper mixed layer and compared them with measurements of turbulent fluctuation near the sea floor. He found a scale similarity in some range of wave members between the two layers of turbulence. L. Cavaleri and S. Zecchetto, reported that the field measurements of Reynolds stress are strongly associated with active wind forcing and with the higher and steeper wave, implying the importance of nonlinear effects. S. Leibovich, Cornell University, summarized some new theoretical results of dynamics of Langmuir cirulations in a stratified ocean; oscillatory and aperiodic convection and self-arresting phenomenon of Langmuir circulations generating their own thermoclines. S. Mizuno presented laboratory experimental findings of Langmuir circulations by the interaction of crossed waves and wind-induced currents and compared them with the numerical solution of the Craik-Leibovich theory with good agreement in the downwelling region. Two more papers on Langmuir circulation were presented by T. Ichiye and his co-workers in the poster session.

- Mixed Layer Model and Climate

J. D. Woods, Universität of Kiel, West Germany, presented a progress report on a research program in which one-dimensional models are being used to investigate the influence of solar heating on the mixed layer and Ekman flow, and reviewed the main results of four papers to this objective. P. Gasper, Université Catholique de Louvain, Belgium, discussed the calibration and results over several years of simulation of an oceanic mixed layer model suitable for climatological studies, and showed that the use of a stability-dependent turbulent dissipation considerably enhances the accuracy of the prediction. G. A. McBean, Atmospheric Environment Service, and M. Miyake, Institute of Ocean Sciences, Canada, described the deduced net effect of atmospheric forcing based on data collected during the Storm Transfer and Response Experiment, and compared them with the observed oceanic changes. F. W. Dobson and S. D. Smith, Bedford Institute of Oceanography, discussed the calibration and prediction of various empirical formula for estimating solar radiation at sea in clear and cloudy conditions. J. Yoshida, Tokyo University of Fisheries, Y. Michuika, Maritime Safety Agency, and Professor Y. Nagata, University of Tokyo, presented some detailed structure of water temperature, salinity, and dissolved oxygen of the surface layer in the frontal zone between the Kuroshio and Oyashio

water in order to study relative importance of interleaving, overturning, double diffusive convection and so on. The last paper of the symposium was given by K. Hanawa and Y. Tobe, Tohoku University. They conducted an extensive intercomparison of three estimation methods of long-term mean heat and momentum transfers across the air-sea interface.

POSTER SESSIONS

- First Poster Session

H. Tomita, Ship Research Institute, Japanese Ministry of Transport, presented an improved version of the nonlinear Schrodinger equation by taking into consideration the induced mean flow that varies with water depth; the equation was applied to the instability analyses for steeper wave trains. T. Hino, Ship Research Institute and H. Miyata and H. Kajitani of the University of Tokyo discussed their numerical and experimental analyses of nonlinear deformation of ocean waves on two- and three-dimensional sand bars. Their results from the finite-difference scheme can also simulate spilling breakers; they report good agreement with experiments using a new grid projection method. M. Hattori and T. Aono of Chuo University presented their laboratory experimental observations on turbulence structures under spilling breakers on a sloping beach. Nonstationarity and intermittency of the turbulence are intensified during the passage of the wave crest, and large-scale turbulent spots are formed near the bottom during the passage of the wave through. Y. Sasaki, I. Asanuma, K. Muneyama, and Y. Tozawa, Japan Marine Science and Technology Center, studied the effects of ocean surface roughness on emissivity and reflectivity of microwave radiation based on field measurements, and applied their method for prediction of the sea surface temperature. Y. Toba and S. Kawai of Tohoku University, K. Okada of the Japan Weather Association, and H. Iida of Kyoto University gave an updated wave prediction model based on hybrid coupling the wind-wave using a single parameter prognostic equation, and with the swell expressed in frequency components. A comparison of the post hoc results with the actual wave field measurements showed promising agreement. L. Schmied, Service Technique des Phares et Balises (France) set forth their data some on the statistical characteristics of the sea-state cycle, i.e., the cycle of the growth and the decay of the sea state under the passage of a storm. Their work was based on several years of wave records in the North Sea. K. Okuda, Tohoku Regional Fisheries Research Laboratory, used flow visualization techniques for observing the structure of the boundary layer under wind waves. He noted a conspicuous internal vortical structure relative to the individual wave crest. Also, the structure of organized motion shows some differences from that found in the wall boundary layer.

- Second Poster Session

S. Kanari and M. Koga, Hokkaido University, gave real measurements of the evolution of fine velocity and temperature profile in the ocean mixed layer. P. J. Hendricks, G. R. Stegen, and R. D. Muench, Science Applications, Inc., took temperature and salinity profiles along transects underlying the Bering Sea marginal ice zone during midwinter; these indicated that a well-developed frontal structure is regularly present beneath the outer marginal ice zone. A. F. Blumberg *et al.*, Dynalysis of Princeton (U.S.A.), received results from the field measurement and numerical modeling of circulation in the Santa Barbara channel. Y. Toba and his colleagues at Tohoku University gave an up-to-date review of their measurements of the horizontal processes in the formation of sea surface temperature, especially in the seas adjacent to the western boundary current. The analysis showed the importance of small-scale warm water bands torn off from the main current. M. Carnes and T. Ichiye, Texas A&M University (U.S.A.), have been working on the

numerical modeling of Langmuir circulation; they showed that the length and time scale of the governing equation depends only on the wind speed for oceanic conditions. Thus their numerical results yield main features of the field observation of Langmuir cells. T. Ichiye, J. R. McGrath, and M. Howard, Texas A&M University (U.S.A.), also directed their research toward numerical modeling of Langmuir circulation; they confirm the contribution of three-dimensional wave breaking to the sharpness of the current speed peak at the surface convergence lines.

INTERNATIONAL MEETINGS AND EXHIBITIONS IN THE FAR EAST

1985-1988

Compiled by Seikoh Sakiyama

The Australian Academy of Science, the Japan Convention Bureau, and the Science Council of Japan are the primary sources for this list. Readers are asked to notify us of any upcoming international meetings and exhibitions in the Far East which have not yet been included in this report.

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Date	Title	Site	For Information, contact
January 8-14	Chemtech 85	Bombay, India	Chemtech Secretariat Taj Building 3rd Floor 210 Dr. D.N. Rd. Bombay 400 001
January 14-15	Automation Asia '85; Instrument Society of America and Society of Manufacturing Engineers Floating Exhibition	Seoul, South Korea	Exhibits Development Manager, SME 1 SME Drive P.O. Box 930 Dearborn, MI 48121 U.S.A.
January 23-26	The 6th Annual Electro-Optics and Laser International Japan '85 (Exhibition)	Tokyo, Japan	Cahners Exposition Group Shinjuku-Mitsui Building No. 2 3-2-11, Nishi-Shinjuku Shinjuku-ku, Tokyo 160
January 23-26	Internepcon Semiconductor Japan '85 (Exhibition)	Tokyo, Japan	Cahners Exposition Group Shinjuku-Mitsui Building 3-2-11, Nishi-Shinjuku Shinjuku-ku, Tokyo 160
January (tentative)	The 26th Concourse of Invention (Exhibition)	Tokyo, Japan	Japan Institute of Invention and Innovation 2-9-14, Toranomon Minato-ku, Tokyo 105
February 3-7	The 5th International Congress: Transportation	Baguio City, Philippines	PCOC, 2F, Proyal Bay Terrace United Nations Avenue Ermita P.O. Box 4486 Metro Manila

1985 Continued

Date	Title	Site	For Information, contact
February 10-15	Symposium on the Interface Between Theory and Experiment	Canberra, Australia	Dr. Leo Radon Research School of Chemistry Australian National University Canberra, A.C.T. 2601
February 11-14	Polymer 85: Characterization and Analysis of Polymers, International Polymer Symposium	Melbourne, Australia	Polymer 85, Royal Australian Chemical Institute 191 Royal Parade Parkville, Victoria 3052
February 12-15	'85 Mechatronics Japan	Tokyo, Japan	Nihon Keizai Shimbun Company, Ltd. 1-8-5, Ohtemachi Chiyoda-ku, Tokyo 100
February 11-16	The 2nd Asian Mining Conference and Exhibition (Rescheduled from 5-8 November 1984)	Manila, Philippines	Conference Office Institution of Mining and Metallurgy 44 Portland Place London W1N 4BR U.K.
February 17-20	The 5th National NMR Conference	Sydney, Australia	Dr. R. S. Norton School of Biochemistry University of New South Wales P.O. Box 1 Kensington, N.S.W. 2033
February 18-22	'85 Tokyo Invention Show (Exhibition)	Tokyo, Japan	Japan Institute of Invention and Innovation, Tokyo Branch 2-9-14, Toranomon Minato-ku, Tokyo 105
February 20-22	'85 Office Automation Show (Exhibition)	Tokyo, Japan	Nippon Administrative Management Association, Osaka Head Office Osaka Science Museum 1-8-4, Utsubo-Hommachi Nishi-ku, Osaka 550
February 27-March 1	'85 Clean Room Technology (Exhibition)	Tokyo, Japan	Nihon Kogyo Shimbun Company, Ltd. 1-7-2, Ohtemachi Chiyoda-ku, Tokyo 100

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Date	Title	Site	For Information, contact
February (tentative)	The 5th International Congress of Pacific Science Association	Baguio, Philippines	Dr. Paulo Campos National Research Council of the Philippines Gen Santos Avenue Bicutan, Taguig Metro Manila
February (tentative)	Carbon Transport in Major World Rivers	Tianjin, People's Republic of China	Dr. V. Smirnyagin 51 Building de Montmorency 75016 Paris, France
February (tentative)	The 9th Industrial Robot Film Festival (Exhibition)	Tokyo, Japan	Japan Industrial Robot Association Kikai Shinko Kaikan Building 3-5-8, Shiba-koen Minato-ku, Tokyo 105
March 3-10	Fine Ceramics Fair '85 (Exhibition)	Nagoya, Japan	Committee of Fine Ceramics Fair 2-17-22, Sakae Naka-ku, Nagoya 460
Mid-March (tentative)	Concourse of School Children, Teachers and Educators Invention (Exhibition)	Tokyo, Japan	Japan Institute of Invention and Innovation 2-9-14, Toranomon Minato-ku, Tokyo 105
March 17-September 16	The International Exposition Tsukuba, Japan, 1985	Tsukuba, Japan	Japan Association for the International Exposition Tsukuba, 1985 2-2-2, Uchisaiwai-cho Chiyoda-ku, Tokyo 100
March 18-22	The 28th Southeast Asia Iron and Steel Institute Tokyo Conference	Tokyo, Japan	The Japan Iron and Steel Federation Keidanren Kaikan Building 1-9-4, Ohtemachi Chiyoda-ku, Tokyo 100
March 20-25	The 1st Store Automation Show (Exhibition)	Tokyo, Japan	Nihon Keizai Shimbun Company, Ltd. 1-9-5, Ohtemachi Chiyoda-ku, Tokyo 100

1985 Continued

Date	Title	Site	For Information, contact
March 27-29	Electro Gulliver: Tsukuba Expo '85 Children's Conference	Tsukuba, Japan	The Federation of Electric Power Companies Ohtemachi Building No. 446 1-6-1 Ohtemachi Chiyoda-ku, Tokyo 100
March (tentative)	Annual National Conference of the Institution of Engineers, Australia	Melbourne, Australia	LtCol. J.A. McDonald Secretary, Victoria Division Institute of Engineers, Australia National Science Center 191 Royal Parade Parkville, Victoria 3052
April 2-6	Wire Tokyo 85: The 2nd International Wire Exhibition	Tokyo, Japan	Dr. Frank Hodgson Director of Public Relations Mack-Brooks Exhibitions 62 Victoria Street St. Albans AL1 3XT U.K.
April 10-11	World Teleport Conference II	Tokyo, Japan	World Trade Center of Japan 2-4-1, Hamamatsu-cho Minato-ku, Tokyo 105
April 15-19	Eighth Australian Symposium on Analytical Chemistry	Melbourne, Australia	Eighth ASAC G.P.O. Box 1929 Canberra, A.C.T. 2601
April 23-26	Computer Graphics Tokyo '85	Tokyo, Japan	Professor Tosiyasu L. Kunii Department of Information Science Faculty of Science University of Tokyo 7-3-1, Hongo Bunkyo-ku, Tokyo 112
May 11-16	The 13th Congress of the Council of Mining and Metallurgical Institutions	Canberra, Australia	Council of Mining and Metallurgical Institutions 44 Portland Place London W1N 4BR U.K.

1985 Continued

Date	Title	Site	For Information, contact
May 13-17	1985 Metals Congress	Victoria, Australia	Dr. A. Brownrigg, 1985 Congress Victorian Branch A.I.M. 191 Royal Parade Parkville, Victoria 3052
May 14-16	1985 Symposium on VLSI Technology	Shima, Japan	Professor Shoji Tanaka Faculty of Engineering University of Tokyo 7-3-1, Hongo Bunkyo-ku, Tokyo 112
May 20-24	The 3rd Conference on Steel Development	Melbourne, Australia	Australian Institute of Steel Construction P.O. Box 434 Milsons Point, N.S.W. 2061
May 27-29	International Convention on QC Circles	Tokyo, Japan	Union of Japanese Scientists and Engineers 5-10-11, Sendagaya Shibuya-ku, Tokyo 151
June 5-7	1985 International Symposium on Circuits and Systems	Kyoto, Japan	Professor Shoji Shinoda Faculty of Engineering Science Chuo University 1-13-27 Kasuga Bunkyo-ku, Tokyo 112
June 23-28	The 14th International Congress of Chemotherapy	Kyoto, Japan	Professor K. Sakai, The Second Division of Surgery Medical School Hospital (attached to) Osaka City University 1-5-7, Asahicho Abeno-ku, Osaka 545
July 14-20	The 6th International Congress for Ultrasound in Medicine and Biology	Sydney, Australia	Dr. R. Jellins P.O. Box R374 Royal Exchange Sydney, N.S.W. 2000
August 6-8	ISGF 85: The 4th International Symposium	Sapporo, Japan	ISGF 85, Institute of Low Temperature Science Hokkaido University Sapporo, Hokkaido 060

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Date	Title	Site	For Information, contact
August 12-16	The 6th International Meeting on Ferro-electricity	Kobe, Japan	Professor S. Nomura Physical Electronics Faculty of Engineering Tokyo Institute of Technology Meguro-ku, Tokyo 152
August 19-24	1985 International Symposium on Lepton and Photon Interactions at High Energies	Kyoto, Japan	Research Institute for Fundamental Physics Kyoto University Oiwake-cho, Kita-shirakawa Sakyo-ku, Kyoto 606
August 19-30	The 23rd General Assembly of IASDPEI (International Association of Seismology and Physics of the Earth's Interior)	Tokyo, Japan	Intergroup Corporation Akasaka Yamakatsu Building 8-5-32, Akasaka Minato-ku, Tokyo 107
August 23-28	The 8th International Conference on Chemical Education	Tokyo, Japan	The Chemical Society of Japan 1-5, Kanda-Surugadai Chiyoda-ku, Tokyo 101
August 25-31	The XV International Grassland Congress	Kyoto, Japan	The Japanese Society of Grassland Science National Grassland Research Institute 768 Nishi-nasuno-machi Nasu-gun, Tochigi 329-27
August 26-28	VLSI '85-International Conference on Very Large Scale Integrated Circuits	Tokyo, Japan	Information Processing Society of Japan Kikai Shinko Kaikan Building 3-5-8, Shiba-koen Minato-ku, Tokyo 105
August 26-30	The 6th International Symposium on Polariza-tion Phenomena in Nuclear Physics	Osaka, Japan	Professor M. Kondo Research Center of Nuclear Physics Osaka University Yamadaoka, Suita, Osaka 530

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Date	Title	Site	For Information, contact
August 29-31	CHDL '85-IFIP (The 7th International Symposium on Computer Hardware Description Languages and Their Applications. International Federation of Information Processing)	Tokyo Japan	Information Processing Society of Japan Kikai Shinko Kaikan Building 3-5-8, Shiba-koen Minato-ku, Tokyo 105
August (tentative)	Coastal Engineering Conference	Melbourne, Australia	The Conference Manager Australia The Institution of Engineers, Australia 11 National Circuit Barton, A.C.T. 2600
August (tentative)	International Association Hydraulic Resources Conference	Melbourne, Australia	The Conference Manager The Institution of Engineers, Australia 11 National Circuit Barton, A.C.T. 2600
August (tentative)	The 21st Congress for IAHR (International Association for Hydraulic Research)	Melbourne, Australia	Mr. Robin Vickery Institute of Engineers Australia 11 National Circuit Barton, A.C.T. 2600
August (tentative)	The 8th IUPAC Conference on Physical Organic Chemistry	Tokyo, Japan	Professor M. Oki Department of Chemistry Faculty of Science University of Tokyo 7-3-1, Hongo Bunkyo-ku, Tokyo 112
September 4-11	The 11th International Teletraffic Congress ITC-11	Kyoto, Japan	ITC-11 Committee Musashino Electrical Communication Laboratory 3-9-11, Midorimachi Musashino, Tokyo 180
September 6-10	1985 Annual Conference of the IIC (International Institute of Communications)	Tokyo, Japan	International Relations Department Japan Broadcasting Corporation 2-2-1, Jinnan Shibuya-ku, Tokyo 150

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Date	Title	Site	For Information, contact
September 9-10	'85 International Conference on Advanced Robotics ('85 ICAR)	Tokyo, Japan	Japan Industrial Robot Association Kikai Shinko Kaikan Building 3-5-8, Shiba-koen Minato-ku, Tokyo 105
September 10-13	The 3rd International Cell Culture Congress	Sendai, Japan	Professor S. Yamane Research Institute for Tuberculosis and Cancer Tohoku University [illegible]-1, Seiko-cho Sendai, Miyagi 980
September 11-13	The 15th International Symposium on Industrial Robots (15th ISIR)	Tokyo, Japan	Japan Industrial Robot Association Kikai Shinko Kaikan Building 3-5-8, Shiba-koen Minato-ku Tokyo 105
September 21-25	World Congress III of Chemical Engineering	Tokyo, Japan	Secretariat, the Society of Chemical Engineers Kyoritsu Building 6-19, Kohinata 4-chome Bunkyo-ku, Tokyo 112
October 14-16	Zinc '85-International Symposium on Extractive Metallurgy of Zinc	Undecided, Japan	The Mining and Metallurgical Institute of Japan 8-5-4, Ginza Chuo-ku, Tokyo 104
October 14-17	International Seminar on Laterite	Undecided, Japan	The Mining and Metallurgical Institute of Japan 8-5-4, Ginza Chuo-ku, Tokyo 104
October 15-18	International Rubber Conference	Kyoto, Japan	The Society of Rubber Industry, Japan Tobu Building 1-5-26, Motoakasaka Minato-ku, Tokyo 107

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Date	Title	Site	For Information, contact
October 19-21	The 4th International Congress of Oriental Medicine	Kyoto, Japan	International Congress Service, Inc. New Kyoto Center Building Higashi-shiokoji Shimogyo-ku, Kyoto 600
November 4-7	HSLA Steels '85 (High Strength Low Alloy)	Beijing, People's Republic of China	Chinese Society of Metals 46 Dongsizi Dajie Beijing
(Undecided)	APAA: The 7th General Assembly 1985 (APAA: Asian Patent Attorneys Association)	Undecided	Japan Asian Patent Attorneys Association Fuji Building 3-2-3, Marunouchi Chiyoda-ku, Tokyo 100
October 19-22	The 5th International Symposium on Rats with Spontaneous Hypertension and Related Studies	Kyoto, Japan	Professor Yukio Iemori Shimane Medical University 89-1, Shioji-cho Izumo, Shimane 693

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Date	Title	Site	For Information, contact
March 16-21	The 10th International Congress of Prestressed Concrete	New Delhi, India	Mr. C. R. Alimchandani Stup Consultant, Ltd. 1004-5-7 Raheja Chambers 213 Nariman Point Bombay 420-021
April 8-11	1986 International Conference on Acoustics, Speech, and Signal Processing	Tokyo, Japan	Simul International, Inc. Kowa Building No. 9, 1-8-10 Akasaka Minato-ku, Tokyo 107
May 11-17	Congress of the International Society of Haematology and the International Society of Blood Transfusions	Sydney, Australia	Dr. I. Cooper, President Haematology Society of Australia Cancer Institute 481 Little Londsdale Street Melbourne, Victoria 3001

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Date	Title	Site	For Information, contact
July (tentative)	International Institute of Welding Annual Assembly 1986	Tokyo, Japan	Japan Welding Society 10-11, Kanda-Sakumacho Chiyoda-ku, Tokyo 101
August 3-7	The 20th Congress of the International Association of Logopedics and Phoniatrics	Tokyo, Japan	Japan Society of Logopedics and Phoniatrics 7-3-1 Hongo Bunkyo-ku, Tokyo 113
August 25-29	The 12th International Congress of the International Association of Sedimentologists	Canberra, Australia	Professor K.A.W. Crook Department of Geology Australian National University P.O. Box 4 Canberra, A.C.T. 2600
August 26-30	International Conference on Martensitic Transformations (ICOMAT-86) in Commemoration of JIM 50th Anniversary	Nara, Japan	ICOMAT-86 The Japan Institute of Metals (JIM) Aoba, Aramaki Sendai 980
August (tentative)	The 7th World Congress on Air Quality	Sydney, Australia	Mr. K. Sullivan Clean Air Society of Australia and New Zealand P.O. Box 191 Eastwood, N.S.W.
September 9-11	The Third International Conference on the Science and Technology "Zirconia"	Tokyo, Japan	The Ceramics Society of Japan 2-22-17 Hyakunincho Shinjuku-ku, Tokyo 160
September 21-25	The World Congress of Chemical Engineering	Tokyo, Japan	The Society of Chemical Engineers, Japan Japan Kyoritsu Kaikan 4-6-19, Honhinata Bunkyo-ku, Tokyo 112
September 22-26	The 9th International Meeting of the International Union of Phlebology	Kyoto, Japan	Professor S. Sakakuchi Hamamatsu University School of Medicine 2nd Surgery Department 3600, Handacho Hamamatsu, Shizuoka 431-31

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Date	Title	Site	For Information, contact
September (tentative)	The 8th International Congress of Psychosomatic Obstetrics and Gynecology	Melbourne, Australia	Dr. L. Dennerstein Department of Psychiatry University of Melbourne c/o Royal Melbourne Hospital Parkville, Melbourne 3052
Undecided	International Microbiological Congress	Perth, Australia	Australian Academy of Science P.O. Box 783 Canberra, A.C.T. 2601

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Date	Title	Site	For Information, contact
March 22-27	The 6th World Conference on Smoking and Health	Kitakyushu, Japan	Dr. Kawano Kitakyushu Municipal Yahata Hospital 4-18-1 Nishi-hommachi Yahata-higashi-ku Kitakyushu, Fukuoka 805

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Date	Title	Site	For Information, contact
April 26-May 3	The 3rd World Biomaterial Congress	Kyoto, Japan	Professor H. Kawahara Department of Dentistry Osaka Dental University 1-47 Kyobashi Higashi-ku, Osaka 540
May (tentative)	The 4th Printed Circuit World Congress	Tokyo, Japan	Japan Printed Circuit Association (JPCA) Tashiro Building 5-11-10 Toranomon Minato-ku, Tokyo 105

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